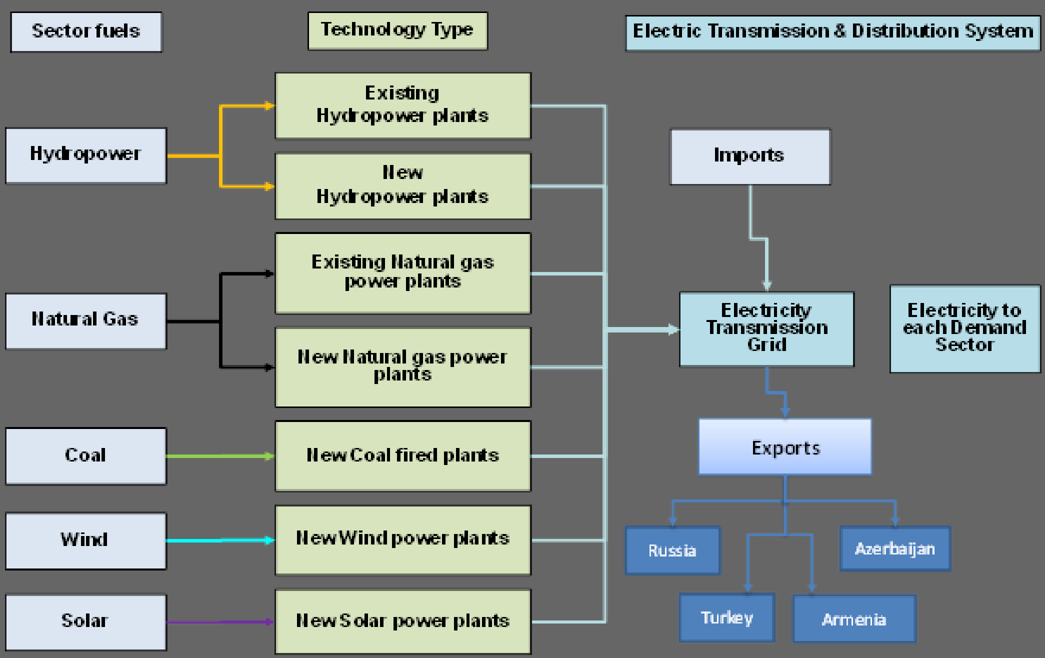
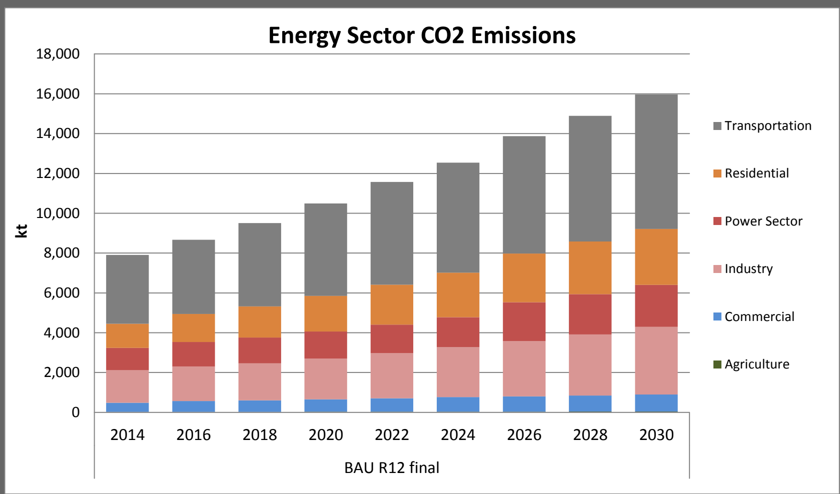
ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES (EC-LEDS) CLEAN ENERGY PROGRAM

Updated MARKAL-Georgia BAU Scenario Report





April 2016

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UPDATED MARKAL-GEORGIA BAU SCENARIO REPORT

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Acronyms

BAU	Business-as-Usual
CH4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
EC-LEDS	Enhanced Capacity – Low Emissions Development Strategy
GfG	Governing for Growth
GDP	Gross Domestic Product
Gg	Gigagram
GWh	Gigawatt Hours
GWP	Global Warming Potential
GHG	Greenhouse Gas
HPEP	Hydro Power and Energy Planning
IEA-ETSAP	International Energy Agency's Energy Technology Systems Analysis Programme
INDC	Indicative National Determined Contribution
Kt	Thousand Tons
Ktoe	Thousand Tons Oil Equivalent
LDV	Light Duty Vehicle
MARKAL	MARKet Allocation
MoE-AD	Ministry of Energy Analytical Department
MW	Megawatts
N_2O	Nitrous Oxide
NDC	National Determined Contribution
NMVOC	Non-methane volatile organic compounds
PJ	Petajoules
PJa	Petajoules per annum
REDP	Regional Energy Demand Planning
RES	Reference Energy System
RESMD	Regional Energy Security and Market Development
SEAP	Sustainable Energy Action Plan
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development

1 Background

This report is an updated version of the MARKAL-Georgia Reference scenario report delivered to Winrock International in April 2015 under the USAID EC-LEDS Clean Energy Program for Georgia. The report summarizes the updates to the MARKAL-Georgia model and documents the projected evolution of the Georgia energy system and the resulting Greenhouse Gas (GHG) emissions under a Business-as-Usual (BAU) scenario. The modifications to the MARKAL-Georgia model were undertaken with the guidance and assistance of the Ministry of Energy, the Ministry of Economy and Sustainable Development and the Climate Change Office in the Ministry of Environment and Natural Resources Protection. In brief, the model base year was updated and recalibrated to the 2014 national energy balance and the model was extended to 2040. Although the results are only reported to 2030, this modification allows the model to incorporate the impacts of extending current policy options beyond 2030.

This BAU scenario represents the projected evolution of the Georgia energy system and the resulting GHG emissions assuming no change in current policies, and it will provide the comparison point for assessing the costs and benefits of potential policy measures for meeting Georgia Nationally Determined Contribution (NDC) commitment arising from the country's indicative submission to the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP) in December 2015. The report is designed to be shared with the LEDS Expert Working Groups and is intended to enable other sectoral experts to review and comment on these results to ensure that best available local data and knowledge is embodied in MARKAL-Georgia.

The principal demand drivers for the BAU scenario are the Gross Domestic Product (GDP) and population growth assumptions, which are highlighted in yellow in Table 1. The GDP growth rates were allocated equally to all demand sectors. All other parameters in the table are derived from these growth rates and the 2014 historical values.

Table 1: GDP and Population Growth Assumptions for BAU Scenario

Demand Driver	2014	2016	2018	2020	2022	2024	2026	2028	2030
GDP growth		3.5%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Population growth		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GDP (2014 M Euro)	12,436	13,321	14,855	16,566	18,473	20,600	22,972	25,616	28,566
Population (1000s)	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730
GDP/pop	3,334	3,572	3,983	4,442	4,953	5,523	6,159	6,869	7,659

In addition to the BAU scenario, the following alternative demand projections were developed with differing GDP and population growth assumptions, as proposed by the Ministry of Environment and Natural Resources Protection.

- GDP growth of 7.3% and Population growth of 0.0%
- GDP growth of 5.6% and Population growth of 0.5%
- GDP growth of 7.9% and Population growth of 0.5%
- GDP growth of 3.6% and Population growth of 0.0%

These alternate demand scenarios are described in Section 5 of this report, which also presents highlights of the energy and emissions results for these scenarios. An Excel workbook accompanies this report, which provides tabular values for all the charts presented in this report.

2 MARKAL-Georgia Overview

The MARKAL-Georgia model has been developed over several years with the support of a series of US Agency for International Development (USAID) regional and national projects designed to better inform policy making and assess future energy investment options. It is built using the MARKAL integrated energy system modeling platform, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP, www.iea-etsap.org). The MARKAL-Georgia model has now been used to examine the role of energy efficiency and renewable energy in meeting anticipated Energy Community commitments and European Union accession directives. The model was updated and used for energy strategy analysis as part of the USAID Hydro Power and Energy Planning (HPEP) project. Most recently under this EC-LEDS project, the model was further updated and used analyze INDC options for Georgia. This latest refinements to the model have been undertaken as part of ongoing process of building capacity within the Ministry of Energy's Analytical Department with an eye towards their long-term stewardship and ongoing use of the model to advise policy and planning.

The key features of the MARKAL-Georgia model are:

- Encompasses the ***entire energy system*** from resource extraction through to end-use demands as represented by a Reference Energy System (RES) network (see the example in Figure 1);
- Employs least-cost ***optimization;***
- Identifies the most ***cost-effective*** pattern of resource use and technology deployment over time;
- Provides a framework for the evaluation of mid-to-long-term ***policies and programs*** that can impact the evolution of the energy system;
- Quantifies the ***costs and technology choices***, and the associated emissions, that result from imposition of the policies and programs, and
- Fosters **stakeholder buy-in** and consensus building.

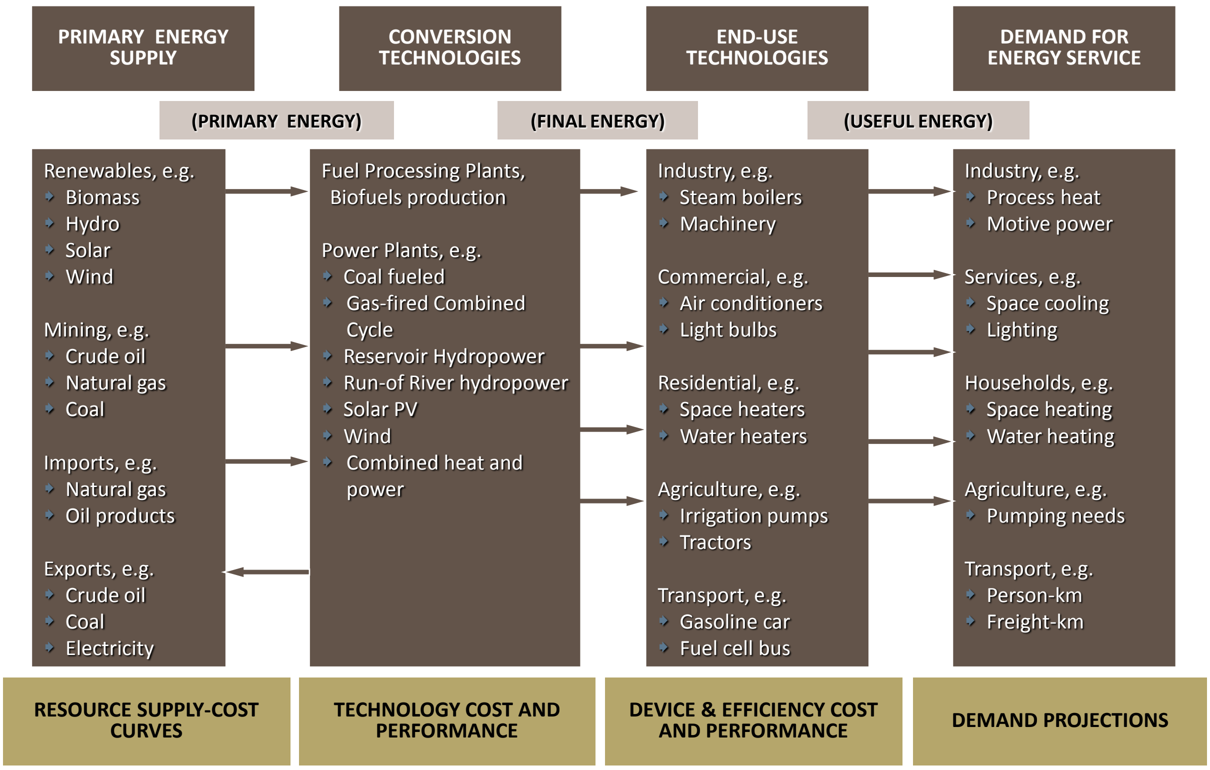


Figure 1: Simplified Reference Energy System

The MARKAL-Georgia model has been substantially revised and updated by EC-LEDS project. The major change involved moving the model's Base Year to 2014 and calibrating the model to the 2014 Geostat energy balance, which is an improvement over the 2012 and 2013 energy balances. In addition, the model was restructured into 2-year periods out to 2040, compared to 3-year periods out to 2036 in the previous version. Furthermore, all input data were reviewed and updated where appropriate. A summary of other changes may be found in Appendix A.

Based on 2014 Geostat energy balance, there are 25 different types of energy carriers currently used in Georgia, each fully depicted in the model.

There are the following demand sectors depicted by the MARKAL-Georgia RES:

- Residential
- Commercial
- Industry
- Transportation
- Agriculture
- Territory Electricity Demand (TED), representing the electricity consumption in Abkhazia.

In addition, there is a separate sector representing the non-energy demands to fully represent all the entries in the 2014 Geostat energy balance.

The power sector describes Georgia's existing and planned power plants individually, including the three thermal plants currently in operation, the Enguri and Vardnili regulating hydro plants, run of river hydropower plants, as well as potential new coal and natural gas-fired power plants.

A detailed description of MARKAL-Georgia will be provided in separate report, the MARKAL-Georgia Guidebook.

3 LEDS Business as Usual (BAU) Scenario

The BAU scenario represents the expected evolution of the Georgia energy system under current policies and practices. This report presents details of the energy consumption and GHG emissions resulting from the total energy system for the updated BAU. Non-energy GHG emissions are not covered.

The MARKAL-Georgia BAU scenario doesn't represent the forecast of evolution of energy system; rather it serves as the comparison scenario for quantifying the costs, benefits, technology changes, fuel switching and other impacts of potential measures that collectively will shape the LEDS strategy for Georgia. The report presents the energy system according to the following sectors:

- Fuel supply and electricity generation;
- Buildings (households and commercial);
- Industry;
- Transportation, and
- Agriculture.

3.1 Fuel Supply and Electricity Generation

Figure 2 shows a simplified RES diagram for the upstream and electricity supply sector as depicted in MARKAL-Georgia. The upstream portion of the energy system is comprised of domestic energy supplies (e.g., coal mining, natural gas wells), imports of electricity, natural gas and oil products, and renewable energy resources. For each of the electricity generation types there may be several instances identifying individual power plants. The electricity transmission and distribution networks in Georgia are also represented, along with imports and exports to four neighboring countries.

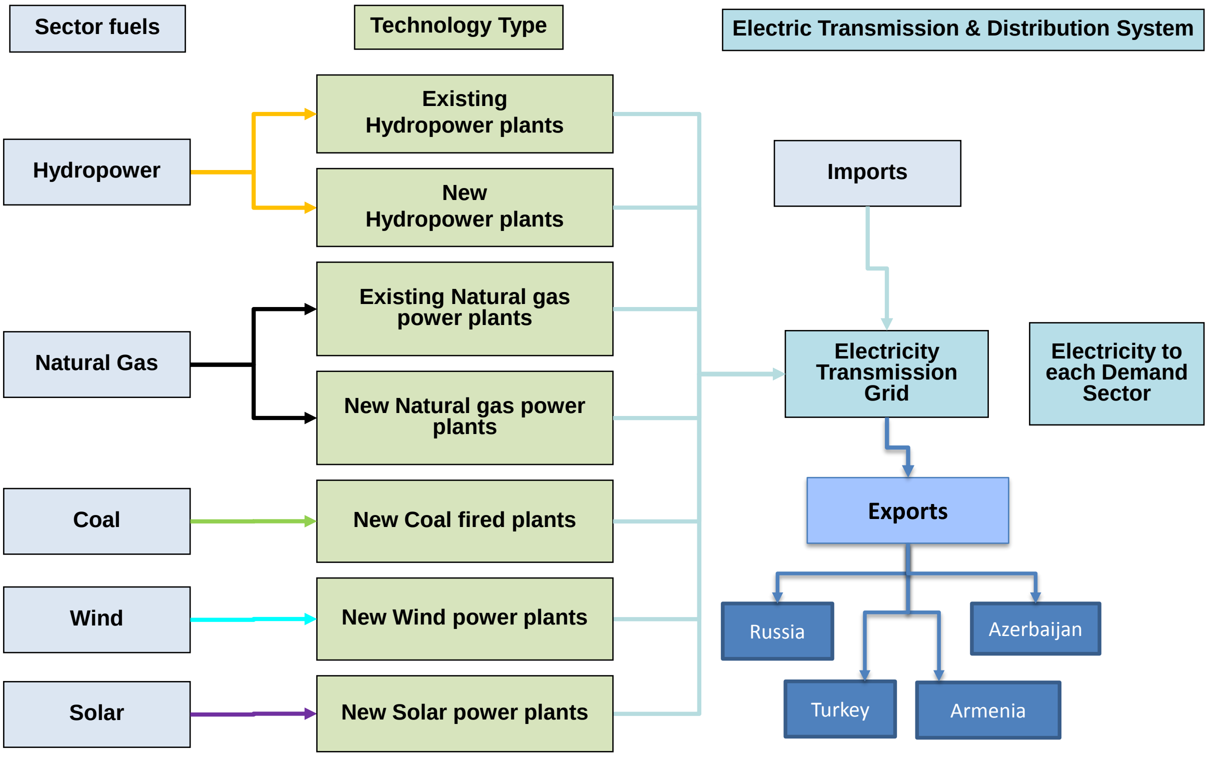


Figure 2: Electricity Generation RES

As shown in Figure 3 in the BAU scenario total primary energy use increases by 90% from 2014 to 2030, with most of the growth occurring for natural gas (1800 ktoe), oil products (1000 ktoe), and coal (490 ktoe).

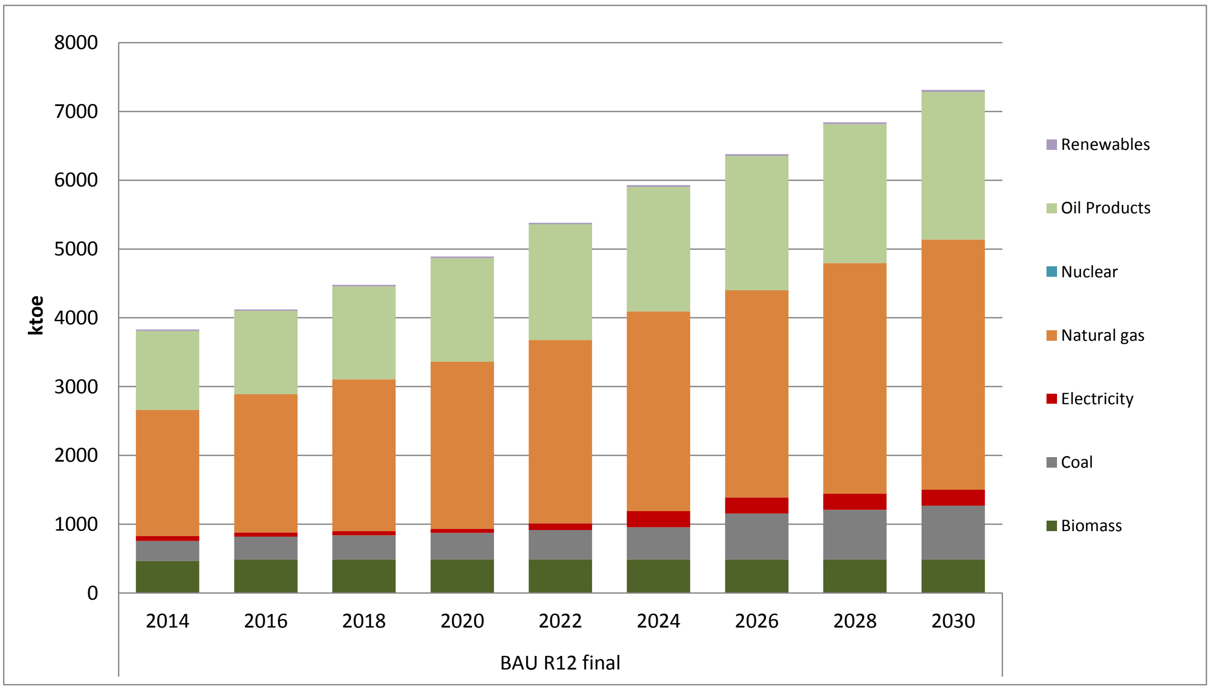


Figure 3: Primary Energy Production and Imports

As shown in Figure 4, imports continue to dominate Georgia's primary energy supply, going from 83.5% in 2014 to 87% of the total in 2030.

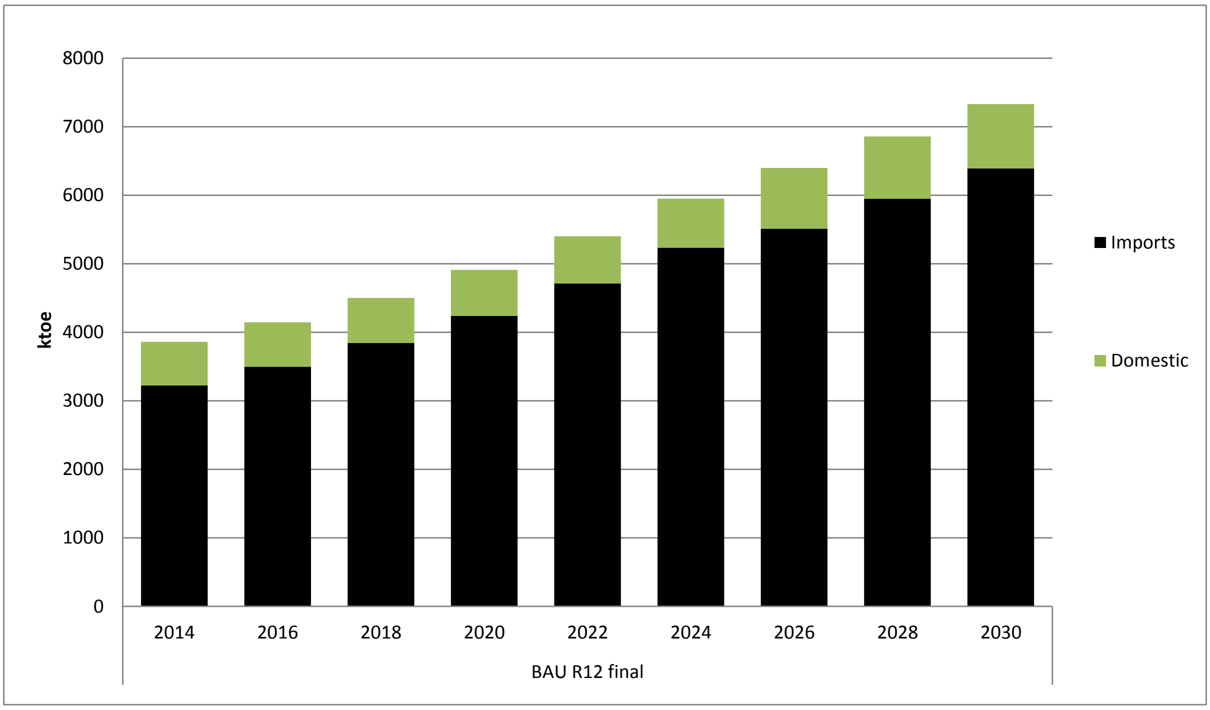


Figure 4: Primary Energy Imports and Domestic Production

Figure 5 provides a breakdown of the primary energy imports, which are dominated by natural gas and refined oil products, with each maintaining shares of approximately 56% and 33% over the 2014 to 2030 time frame.

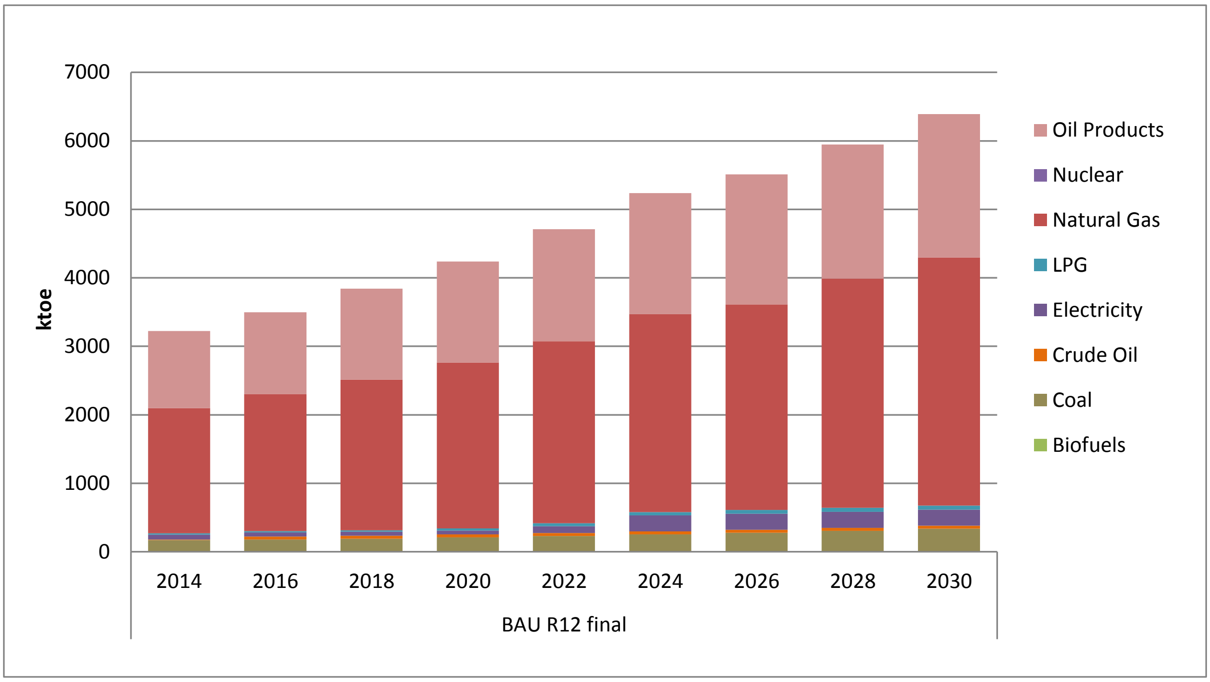


Figure 5: Breakdown of Primary Energy Imports

As shown in Figure 6, total electricity generation and imports increase 71% from 2014 to 2030 with most of the growth occurring from hydropower (19,600 GWh), imports (1868 GWh), natural gas (716 GWh) and coal (696 GWh).

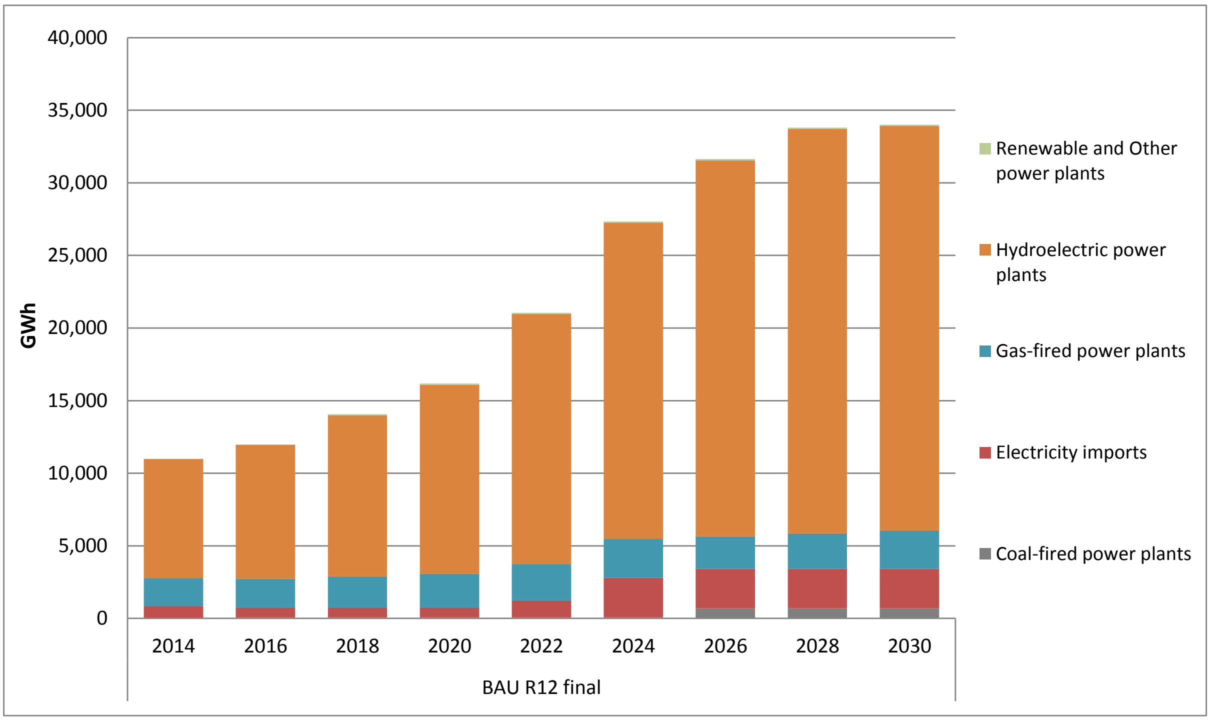


Figure 6: Electricity Generation by Plant Type and Imports

Figure 7 shows the new power plant capacity installed in each 2-year period for the BAU scenario, which adds hydropower capacity in every period, except 2030. In addition, a 220 MW gas-fired plant and a small coal power plant are added in 2016, a 20 MW wind farm in 2018, followed by a 150 MW coal plant in 2020. These non-hydro power plants are planned builds that are specified as part of the BAU scenario.

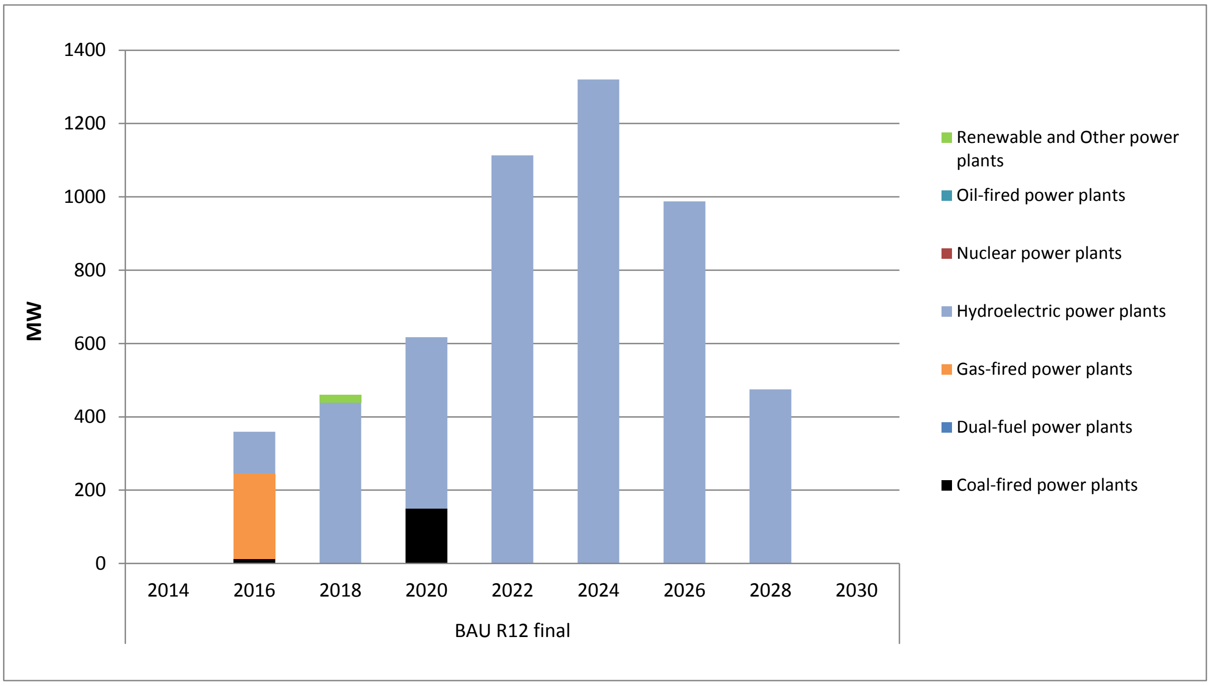


Figure 7: Capacity of New Power Plant Additions (per period)

The electricity generation by all hydropower plants (HPPs) is shown in Figure 8, which also shows when new HPP are constructed. Following the HPPs under construction, new capacity is added from run-of-river HPPs, Nenskra and Khudoni, and new General HPPs.

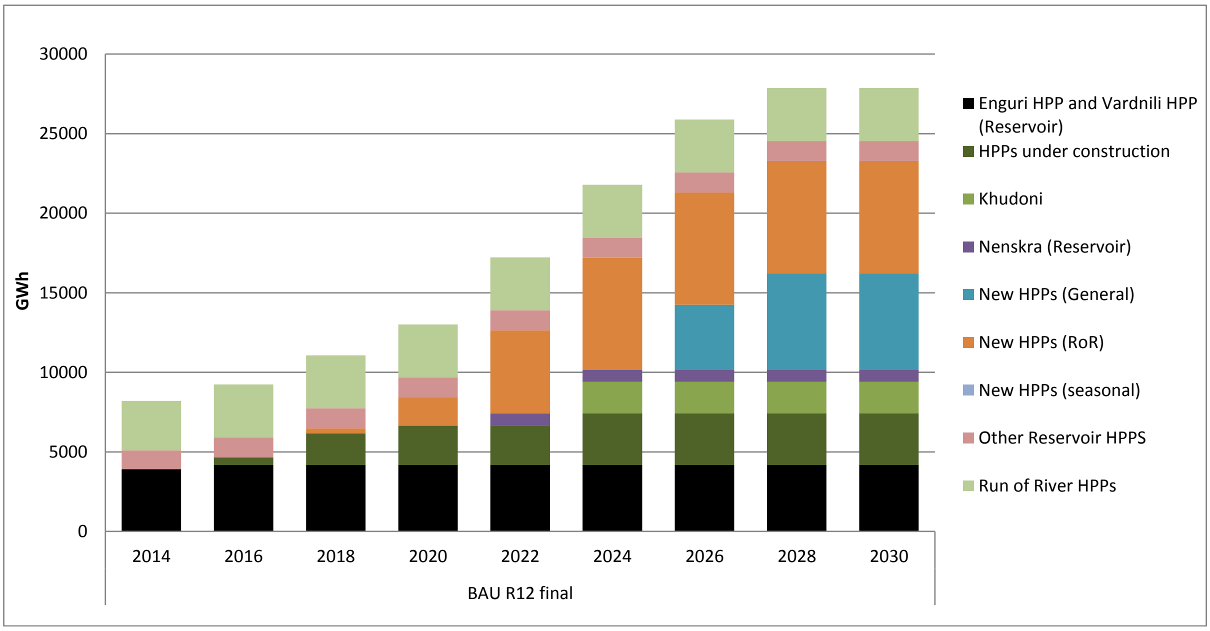


Figure 8: Annual Generation by Hydropower Plant

The High growth of electricity generation and hydro capacity is caused by increased domestic demand, but most importantly by increased electricity exports, which, under this scenario reach up to 16,000 GWh by 2030. Of course this is subject to the market availability in neighboring countries and price of electricity by 2030, as well as possibility of building the corresponding hydro capacity.

The new HPPs (General) represent generic "possible" hydro plants, which are not yet decided upon. They are mainly built for electricity exports, which are cost-effective. If there is not enough electricity export market by 2030 or this extra hydro capacity is not built, the electricity generation will decrease by up to 6,000 GWh, with electricity exports dropping to 10,000 GWh.

It is important to note that building hydropower plants for electricity export doesn't affect the emissions within Georgia, or the emissions growth trajectory. So it doesn't have an impact on LEDS BAU or mitigation actions. The export market and price projections and corresponding hydro capacity availability may need to be subject to revision/improvement if model is used for the analysis of an energy strategy and/or electricity exports.

Figure 9 shows that because the gas-fired power plants are required to provide a fixed percentage of total domestic electricity consumption for load balancing the expanding hydropower capacity, the gas consumption for power generation increases by 25% by 2030. It also shows the addition of the small coal plant under construction and the new coal plant in 2020.

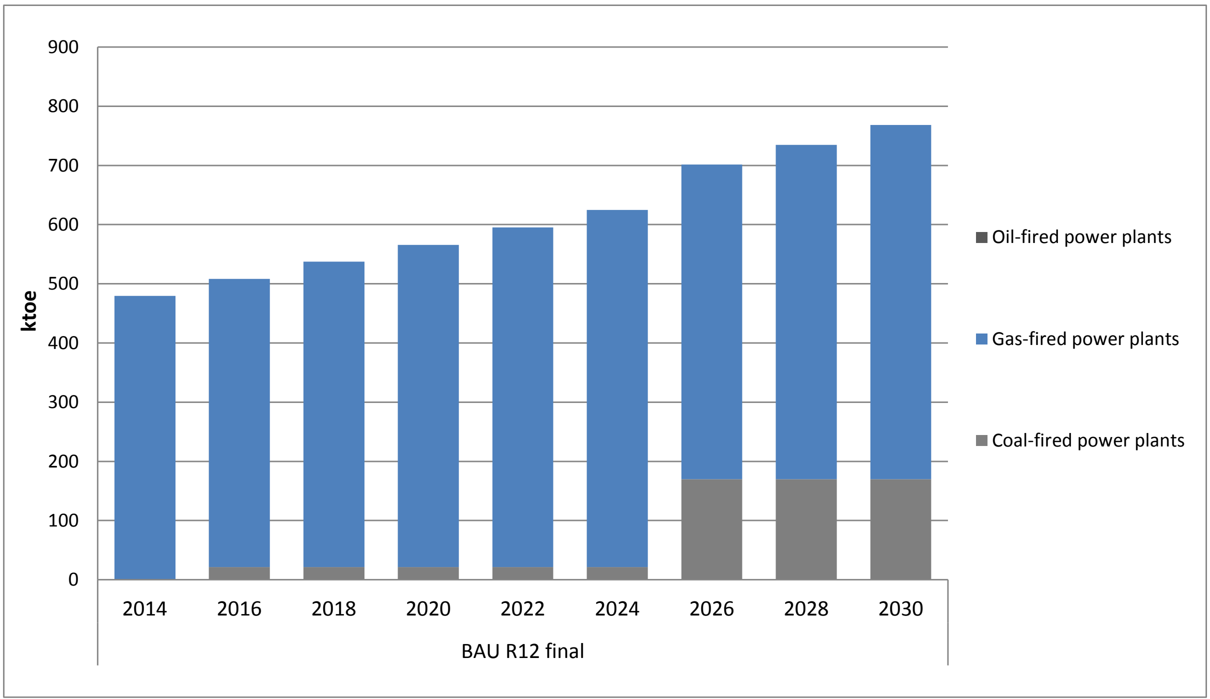


Figure 9: Power Plant Fuel Consumption

3.2 Energy Sector GHG Emissions

As shown in Figure 10, CO_2 emissions from the entire energy system increase by 102% between 2014 and 2030 led by the transportation sector (increasing 3,290 kt), the industry sector (increasing 1,770 kt) and the residential sector (increasing 1,600 kt). Power sector emissions increase by 980 kt.

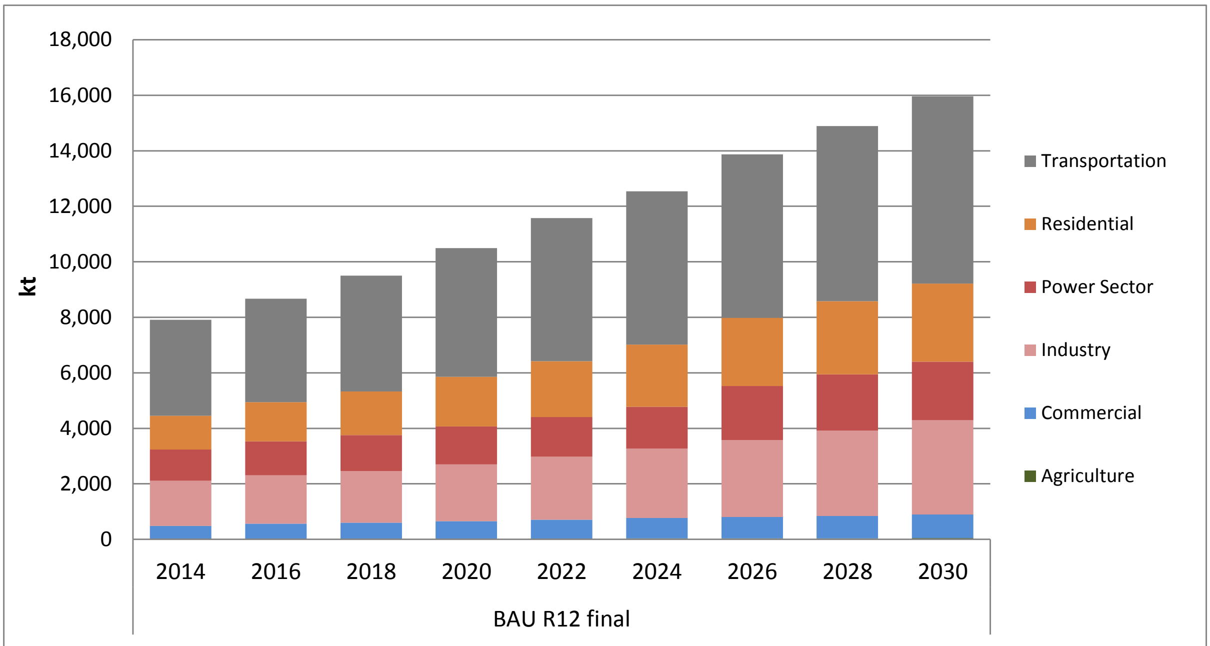


Figure 10: CO_2 Emissions by Sector

The energy related GHG emissions are directly tied to the delivery and consumption of fossil fuels. Total final energy use increases by 88% between 2014 and 2030 with most of the growth occurring for transportation (1,410 ktoe), residential (896 ktoe) and industry (739 ktoe) sectors. Figure 11 shows final energy use by fuel type. The greatest growth is in natural gas use, which grows from 30% of the total in 2014 to 37% by 2030, mainly responsible for pushing up the GHG emission. Electricity, coal, gasoline and diesel also show significant growth, also contributing to the GHG rise.

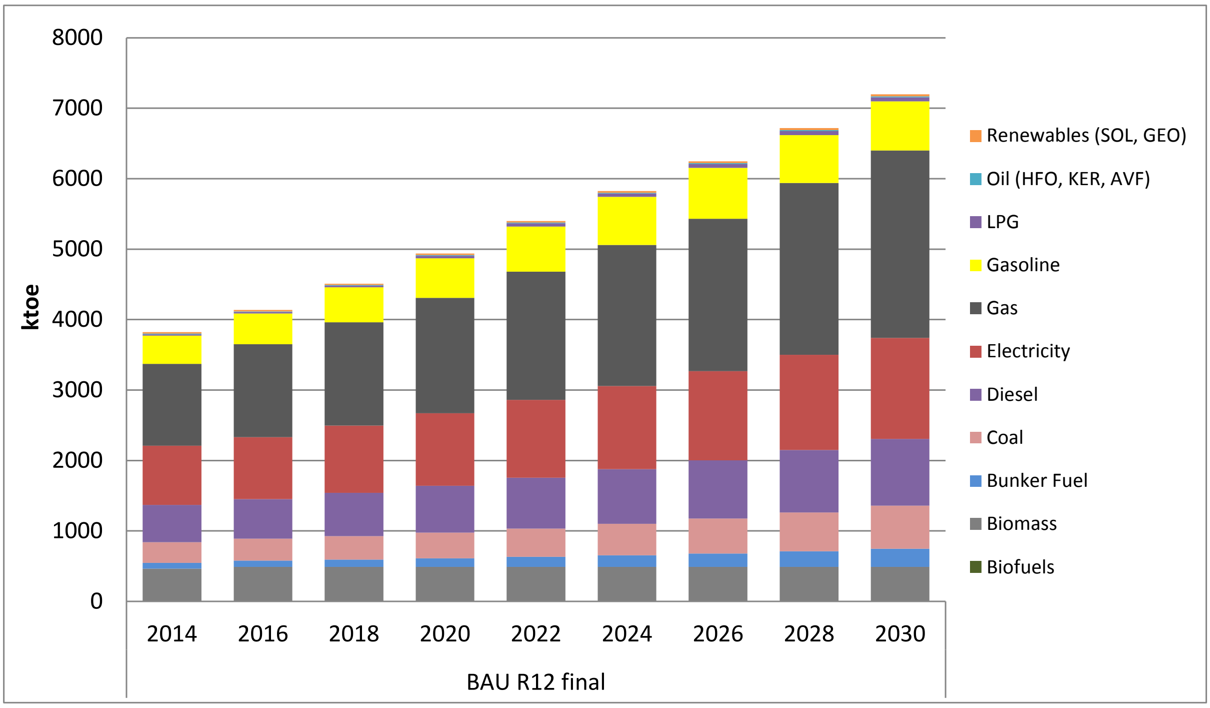


Figure 11: Final Energy Consumption

Given that natural gas makes up the largest share of final energy use in Georgia, Figure 12 shows natural gas consumption by sector, with consumption for the residential sector increasing the most (640 ktoe), followed by transportation (498 ktoe).

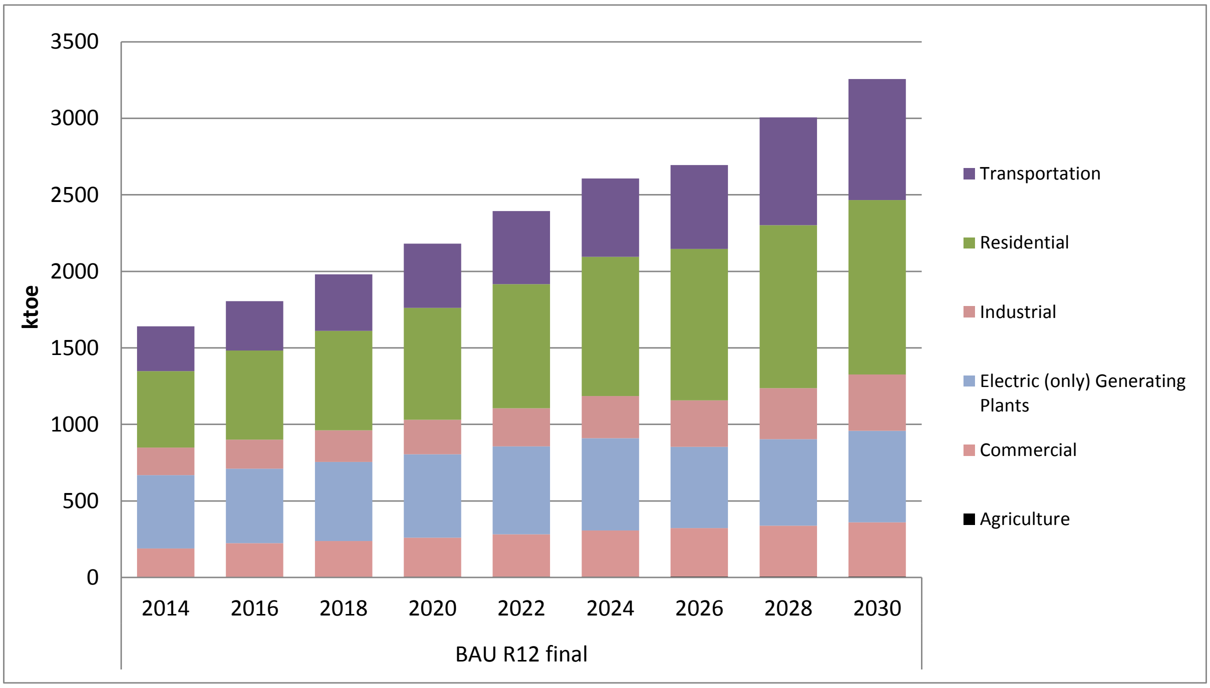


Figure 12: Consumption of Natural Gas by Sector

Figure 13 shows that methane emissions (kt of CH_4) from the entire energy system increase by over 100% between 2014 and 2030 with natural gas distribution network comprising 83% of the total (increasing 58 kt), and coal mining contributing 11% (increasing by 11 kt). The other methane emission sources remain flat.

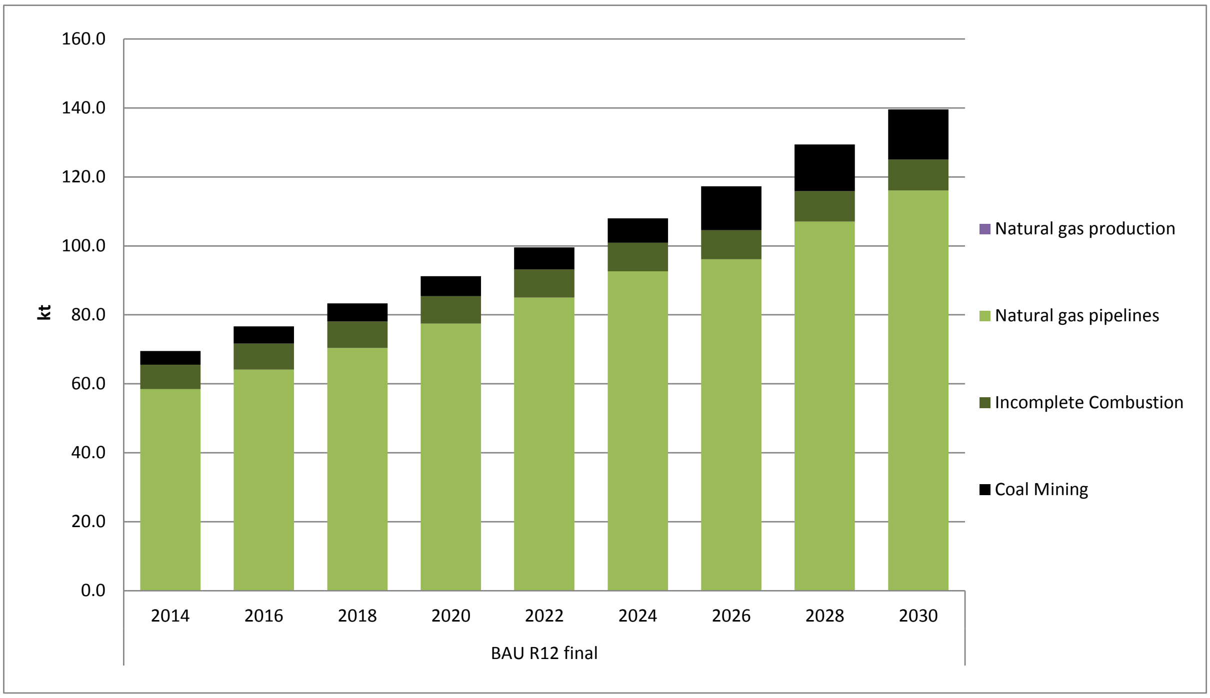


Figure 13: Methane Emissions by Activity

Figure 14 shows N_2O emissions (kt of N_2O) from the energy system, which are due to the incomplete combustion of fuels. These emissions grow at a rate similar to final energy use.

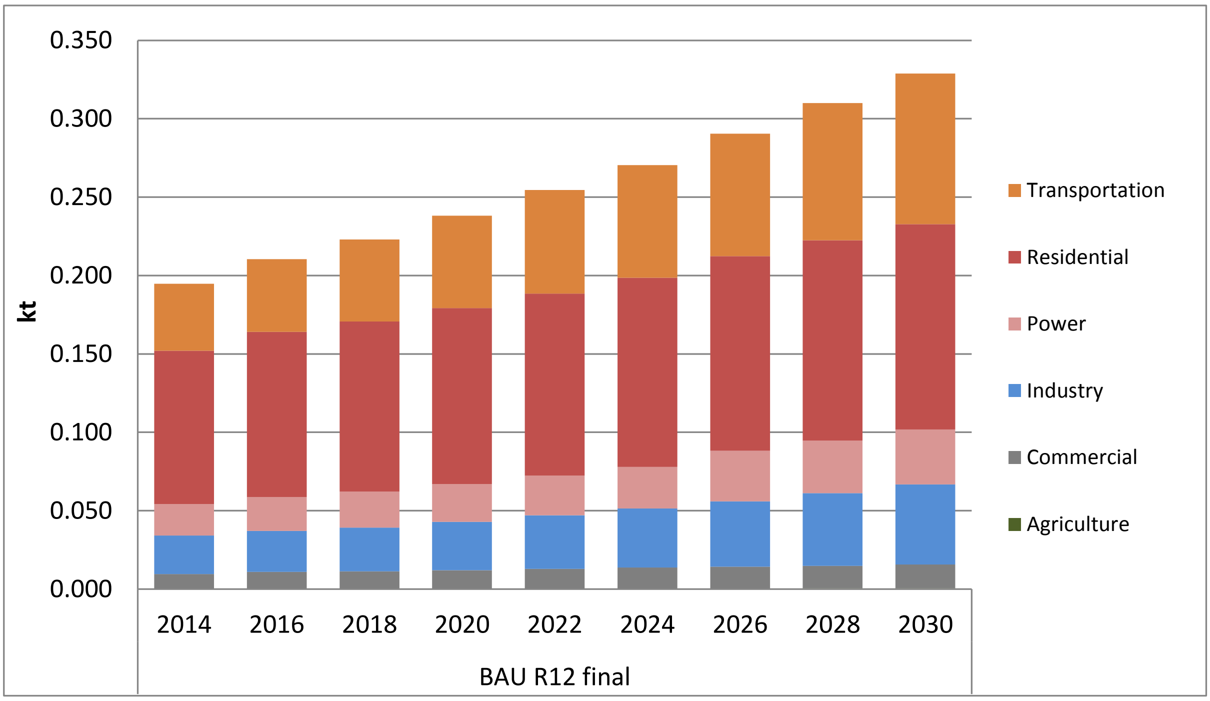


Figure 14: N_2O Emissions by Sector

CO_2 equivalent emissions from the entire energy system are presented in Figure 15, which shows that about 84% of total GHG emissions are due to CO_2 from fuel combustion and that about 15.5% are due to methane emissions from natural gas pipelines and coal mines, with an 0.5% contribution from N_2O.

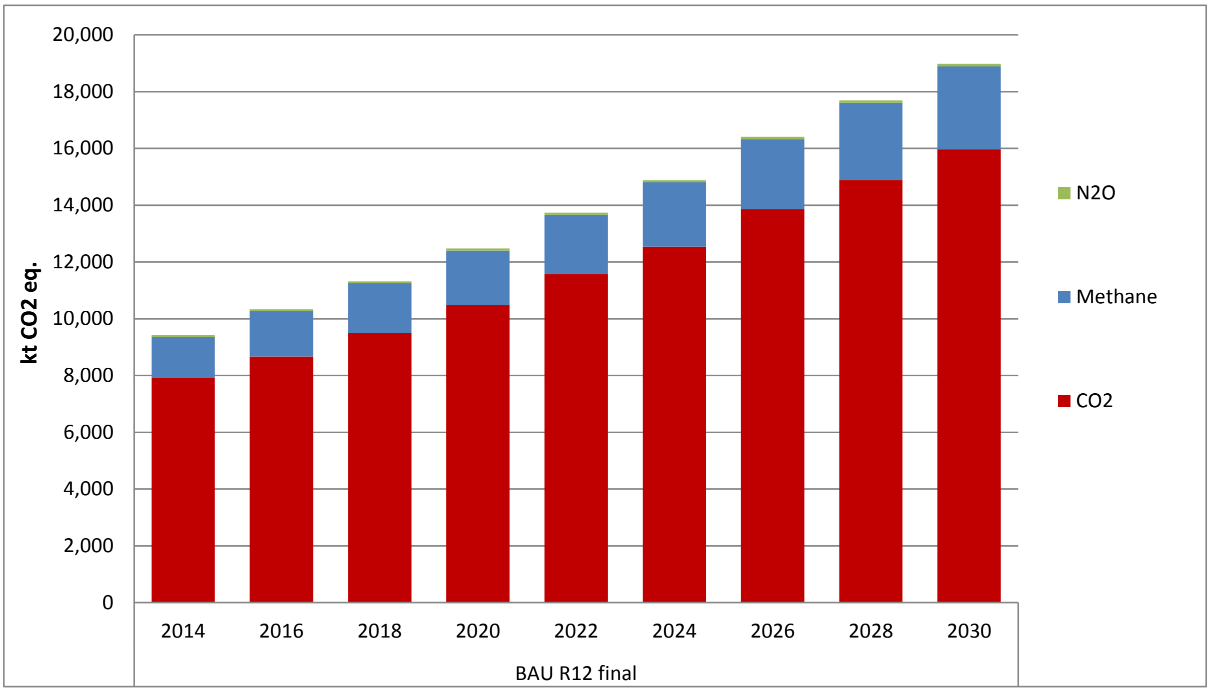


Figure 15: CO_2 equivalent GHG Emissions by Type

3.3 Building Sectors Energy Use and GHG Emissions

In MARKAL-Georgia the buildings sector consists of both commercial (government and services) and residential (households) buildings. A simplified RES diagram of the commercial sector is presented in Figure 16, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes retrofit measures to reduce overall building energy demand.

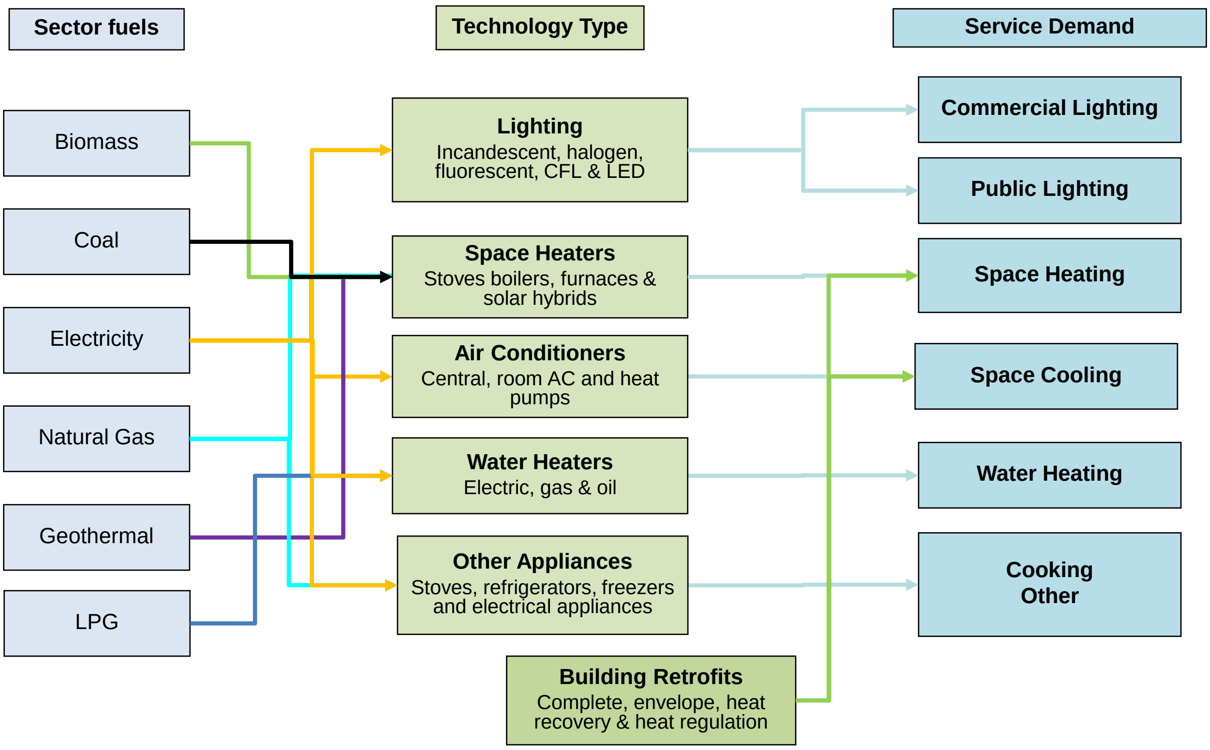


Figure 16: Commercial Buildings RES

As shown in Figure 17, commercial sector energy use increases by 66%, with the most significant growth for natural gas (166 ktoe) and electricity (120 ktoe), with biomass use declining.

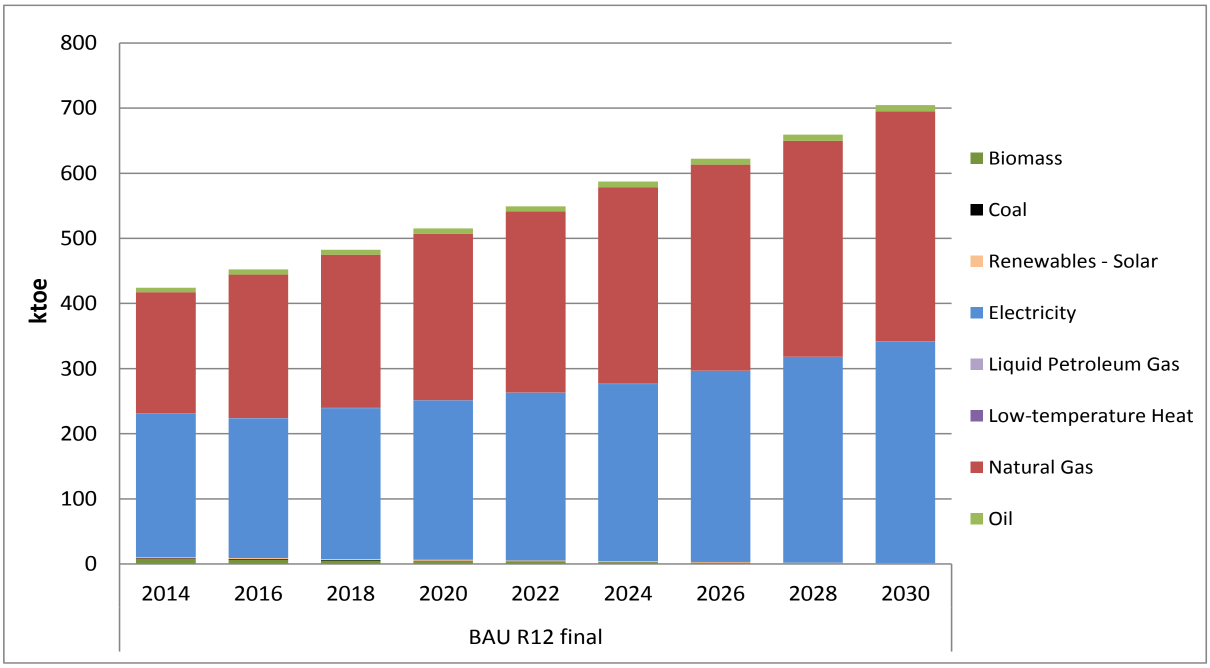


Figure 17: Commercial Energy Use by Fuel Type

Figure 18 shows that commercial energy use by end-use service is dominated by space heating, (increasing 150 ktoe) and other (increasing 84 ktoe). Space heating increases from a 47% to a 50% share while other end-use services increases from 14% to 20%.

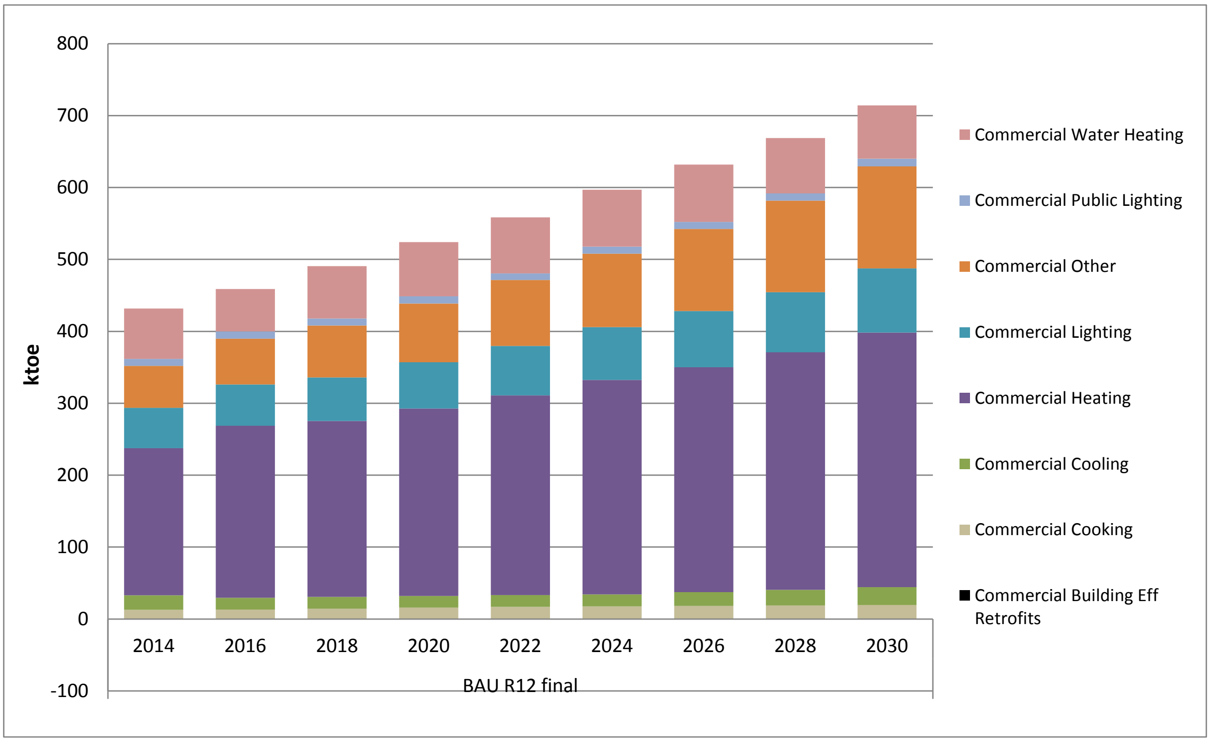


Figure 18: Commercial Energy Use by Energy Service

Figure 19, which provides the direct CO_2 emissions from commercial sector energy use, shows these emissions are also dominated by space heating (91%) and water heating (6%) mainly using gas.

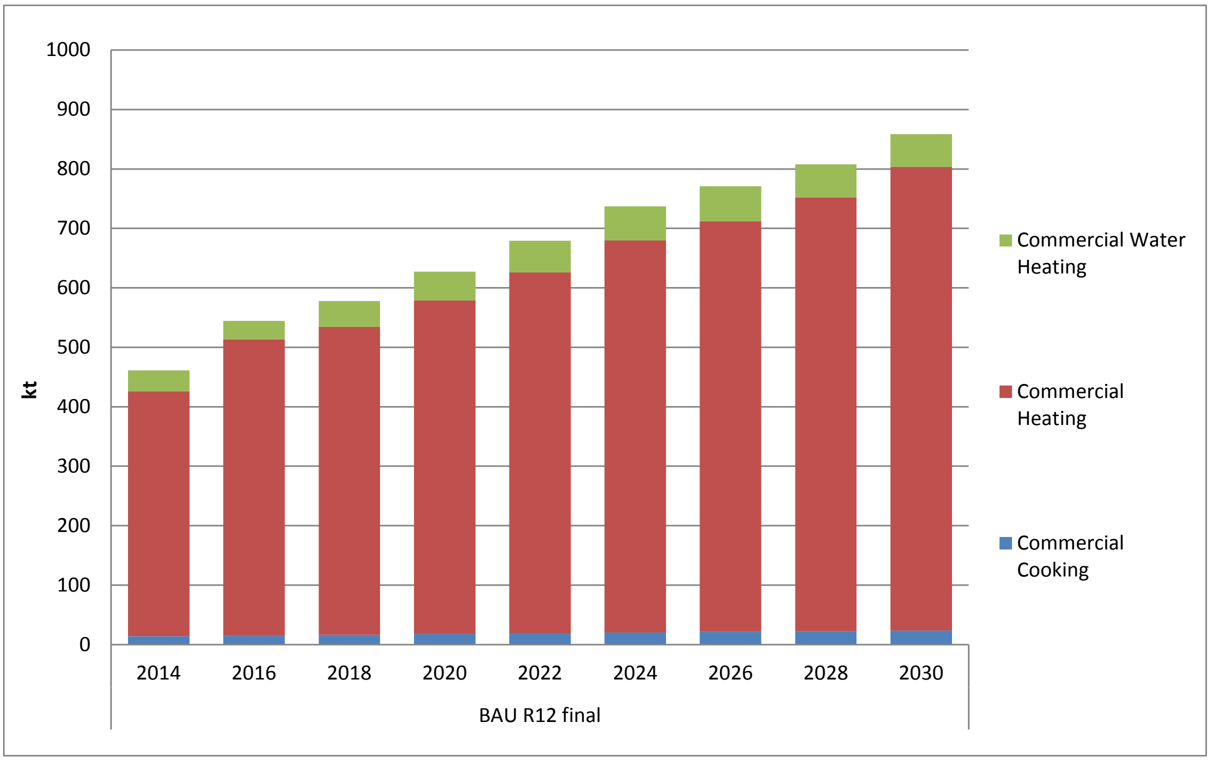


Figure 19: Direct CO2 Emissions by Commercial End-Use Service

The complete set of CO_2 emissions from commercial sector end-uses is shown in Figure 20, where the emissions from electricity consumption are added to the direct CO_2 emissions using the grid emission factor calculated for each period. Emissions from space heating remain dominant, but the share drops from 57% in 2014 to 54% in 2030. The largest percentage increase happens for commercial other, which grows from 15% to 22% of the total emissions.

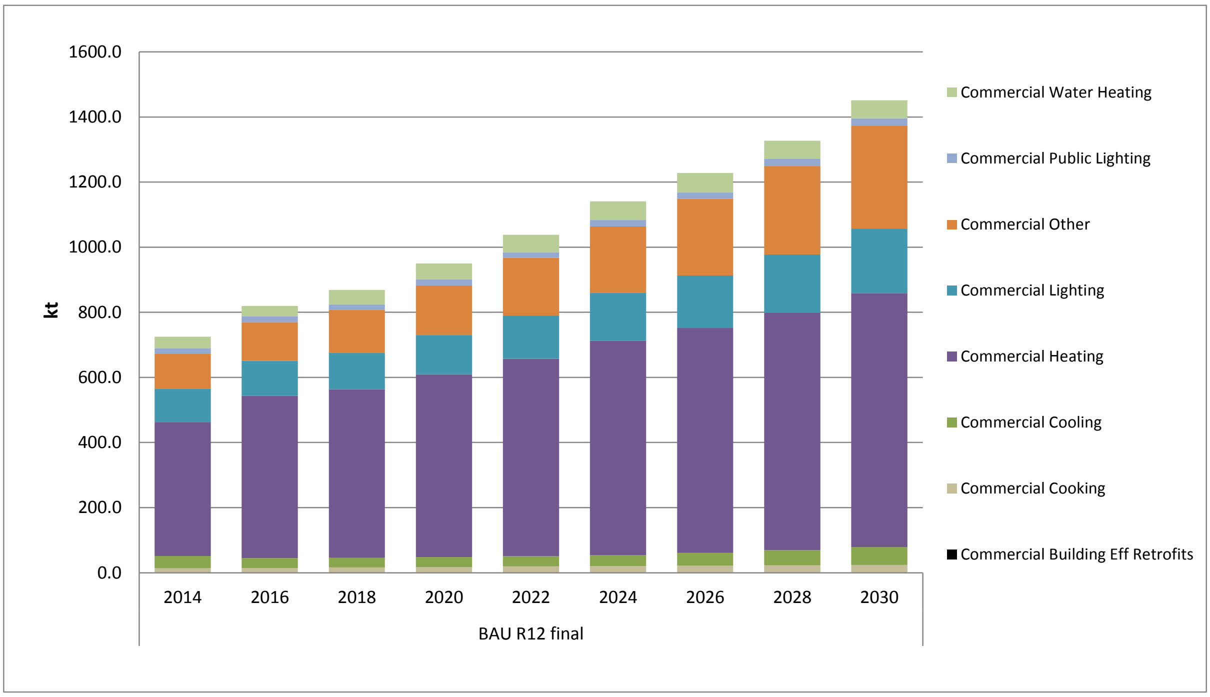


Figure 20: Total CO_2 Emissions by Commercial End-Use Service

A simplified RES diagram of the residential sector is presented in Figure 21, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes insulation measures to reduce overall building energy demand.

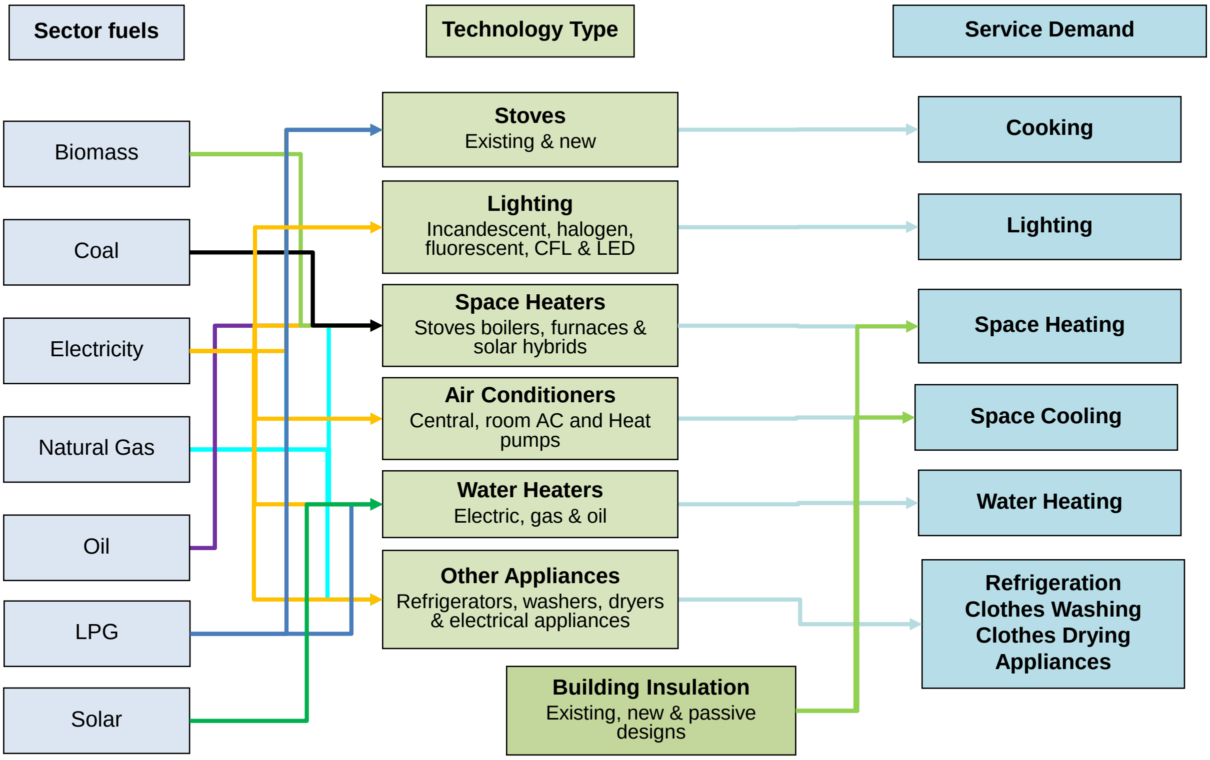


Figure 21: Residential Buildings RES

Residential sector energy use, which is shown in Figure 22, increases most significantly for natural gas (640 ktoe) and electricity (180 ktoe). The natural gas share increases from 42% to 55%, while biomass share reduces from 38% to 23%. The electricity share stays at about 18%.

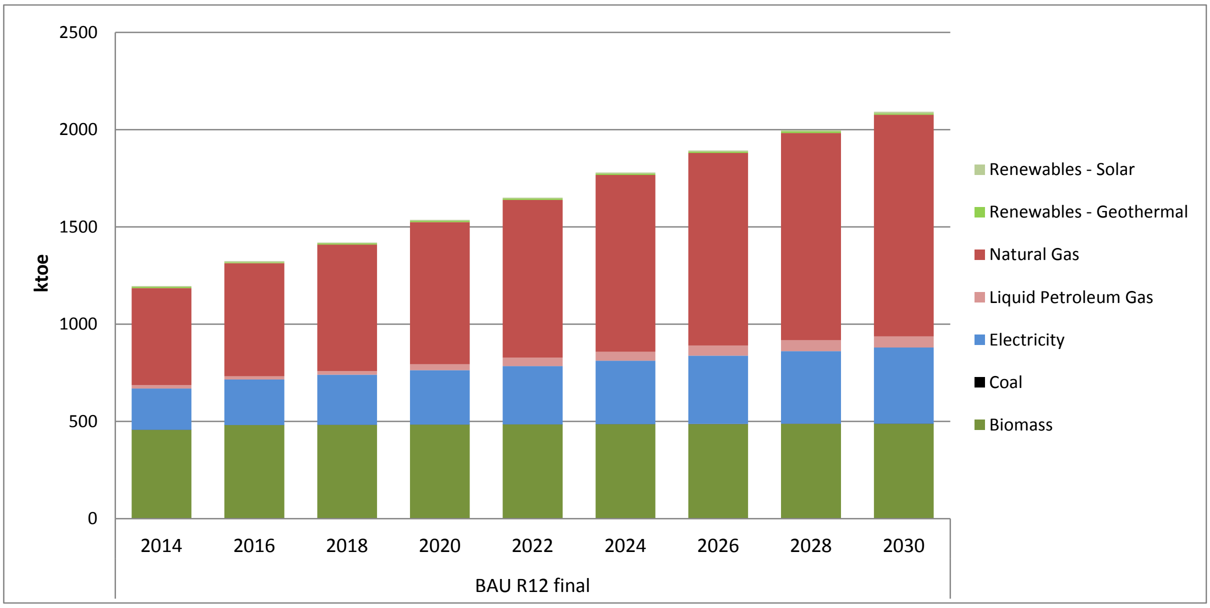


Figure 22: Residential Energy Use by Fuel

Figure 23 shows that residential sector energy use is dominated by space heating (increasing 540 ktoe), which accounts for about 59% of the residential energy use, and water heating (increasing 215 ktoe), which grows from 20% to 22% share the residential energy use.

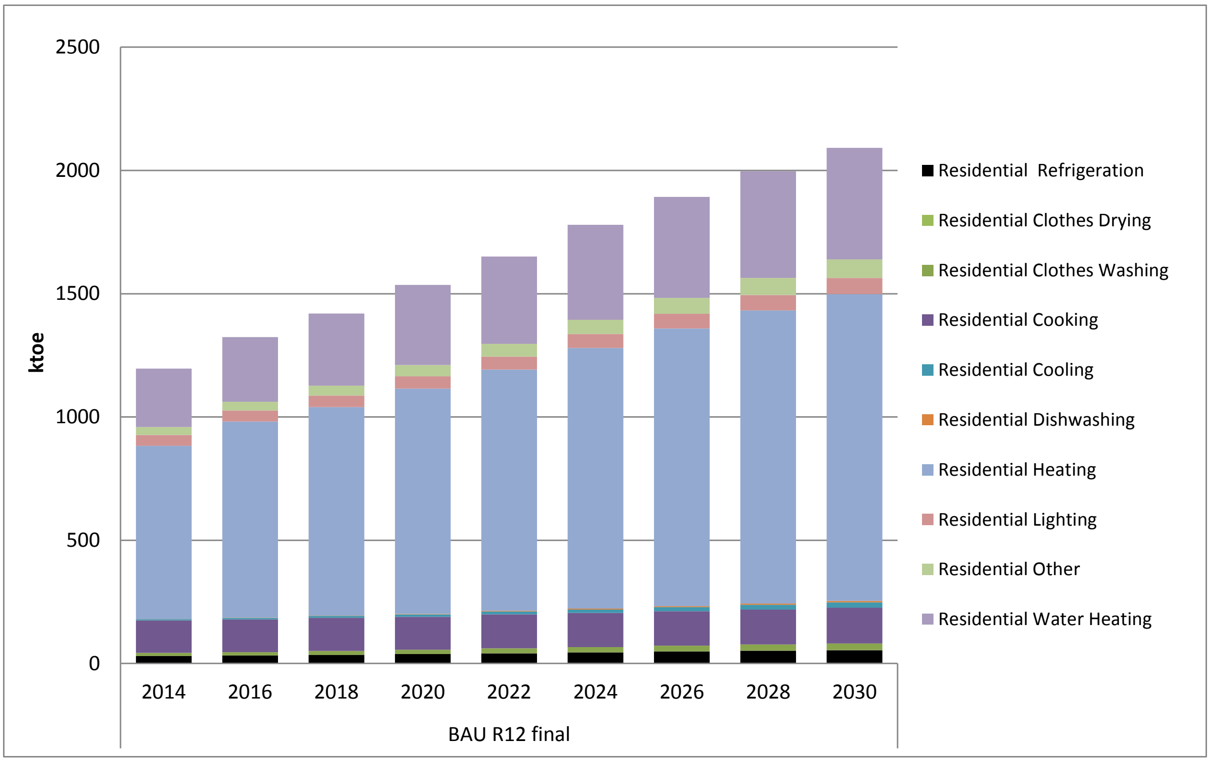


Figure 23: Residential Energy Consumption by End Use

Figure 24 shows that the growth in direct CO_2 emissions from the residential sector is dominated by space heating (69%) and water heating (21%), with emissions from cooking growing slightly based primarily on the increased penetration of natural gas for these services.

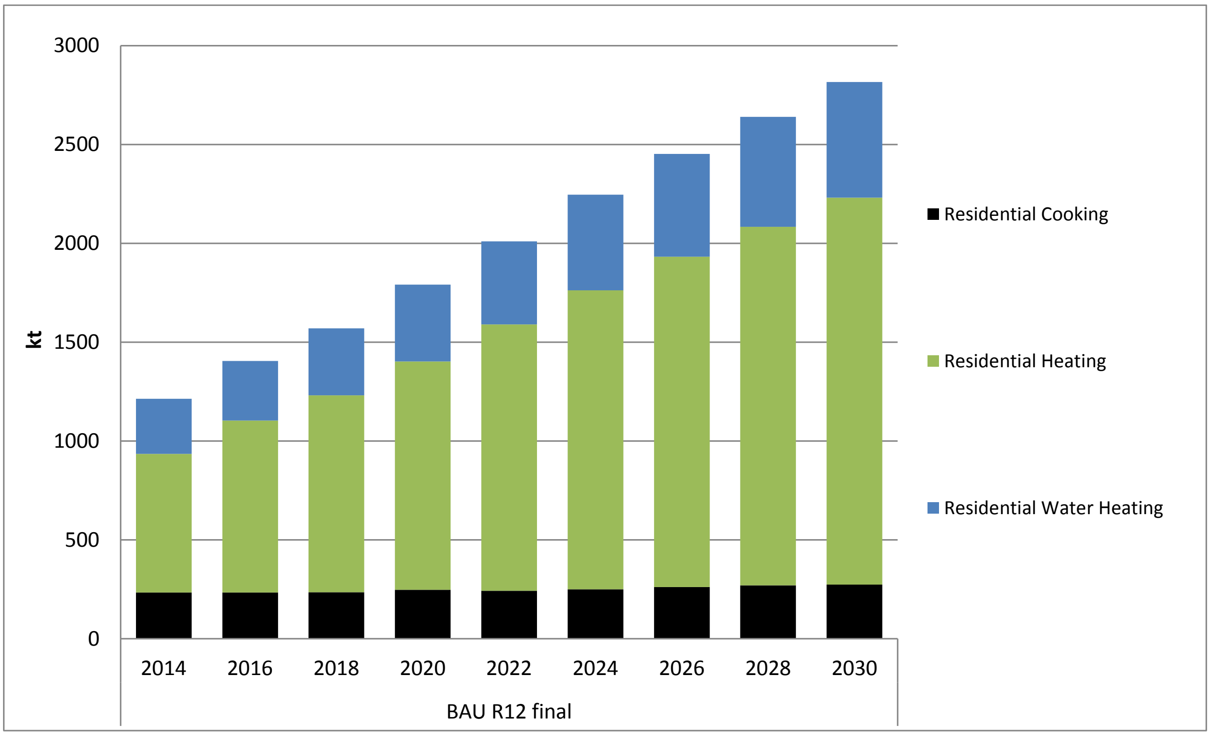


Figure 24: Direct CO2 Emissions by Residential End Use Service

The complete set of CO_2 emissions from residential sector end-uses is shown in Figure 25, where the emissions from electricity consumption are added to the direct CO_2 emissions using the grid emission factor calculated for each period. Emissions from space heating (increasing 1255 kt) and water heating (increasing 307 kt) remain dominant, accounting for 58% and 17% of emissions in 2030.

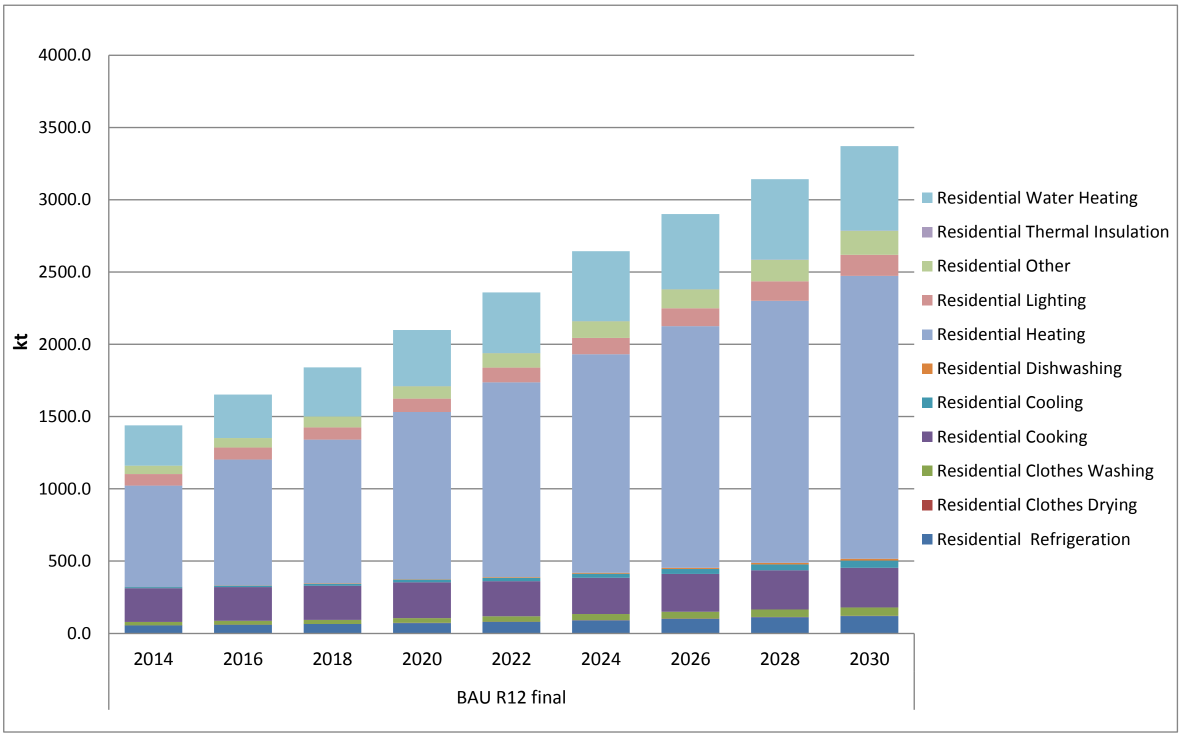


Figure 25: Total CO2 Emissions by Residential End Use Service

3.4 Industry Sector Energy Use and GHG Emissions

The simplified RES for the Industrial sector is shown in Figure 27. Each industrial sub-sector requires process heat and mechanical drive services to produce their associated products.

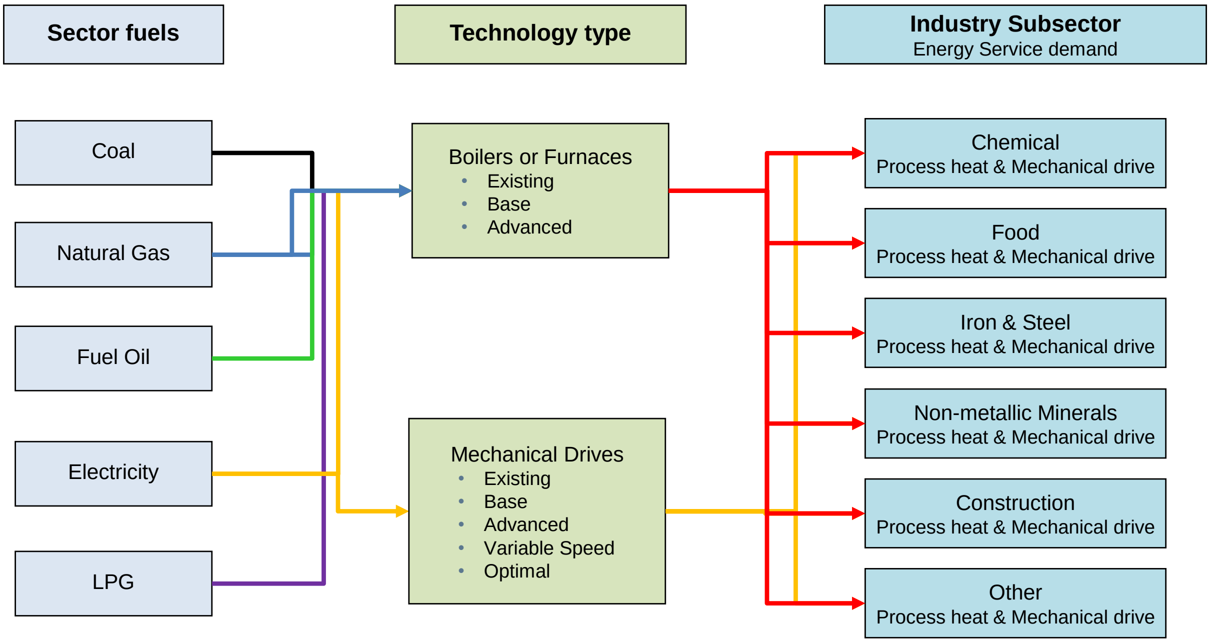


Figure 26: Industry Sector RES

As shown in Figure 27, industrial energy use grows by 106% between 2014 and 2030. Although Iron & steel (32%) and Non-metallic minerals (32%) and are the largest, each industrial subsector grows proportionally, as the demand projection for each is determined by the same GDP and elasticity drivers.

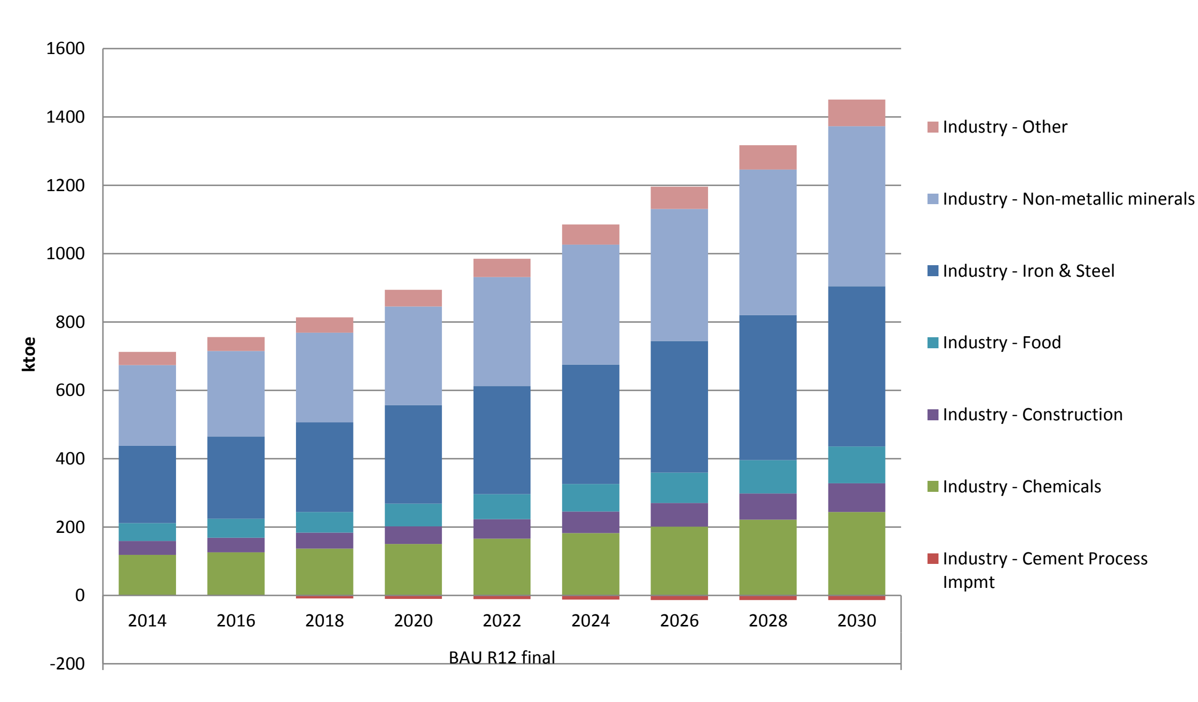


Figure 27: Industrial Energy Use by Subsector

As shown in Figure 28, coal comprises 42% of industrial energy use, followed by electricity (33%) and natural gas (25%).

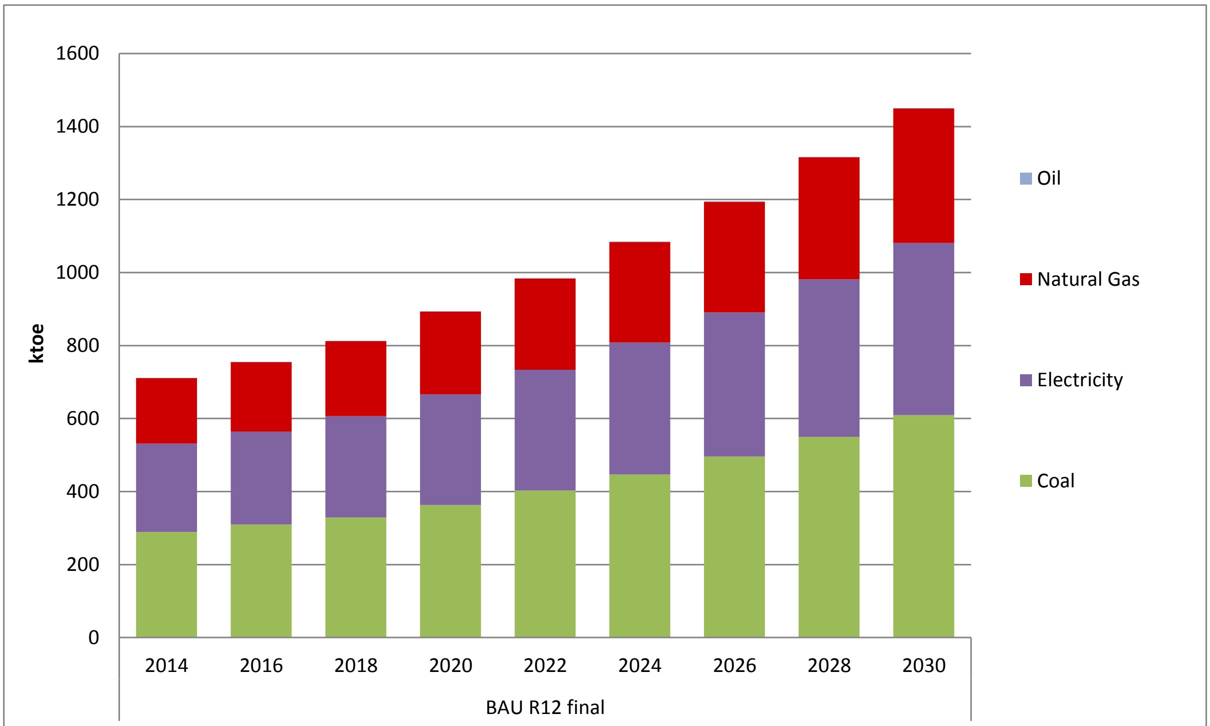


Figure 28: Industrial Sector Energy Use by Fuel

Figure 29 shows both the direct industry sector CO_2 emissions as well as the indirect emissions from electricity consumption in the industry sector. The primary GHG emissions from the sector come from the use of coal and natural gas. Non-metallic minerals (dominated by clinker and cement production) production produces 38% of total industry emissions in 2030, followed by industry-wide electricity use (24%) and iron and steel (22%), with chemicals accounting for 11% and the other subsectors accounting for less than 5% each.

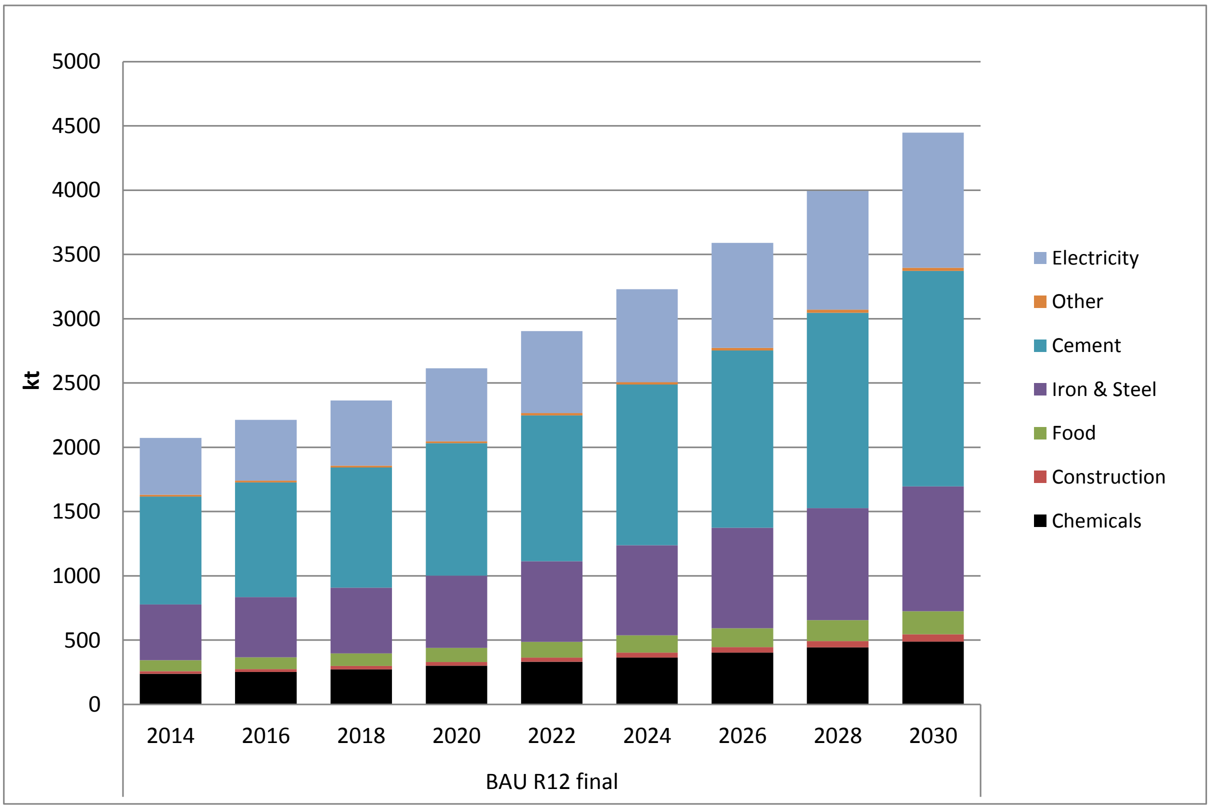


Figure 29: Direct and Indirect CO_2 Emissions from the Industrial Sector

3.5 Transportation Sector Energy Use and GHG Emissions

The transportation sector is sub-divided into passenger and freight transport modes. The total transport sector fuel use, which is shown in Figure 30, grows by 106% between 2014 and 2030, and is dominated by diesel, gasoline and Compressed Natural Gas (CNG).   The largest increase in energy use comes from CNG, which increases by 170% between 2014 and 2030. Diesel use grows faster than gasoline use, but both lose share to CNG.

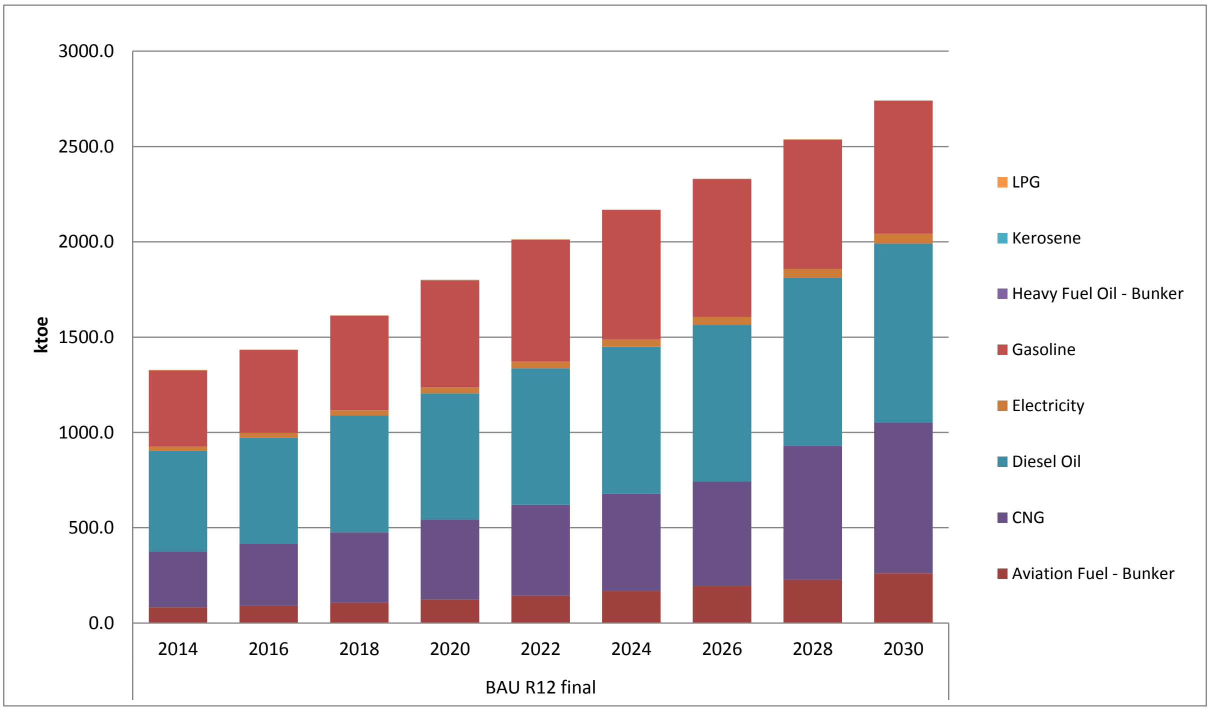


Figure 30: Fuel Consumption for Total Transport Demands

The simplified RES for the Passenger transportation is shown in Figure 31. Each passenger transportation demand uses a suite of vehicle types to deliver the associated service.

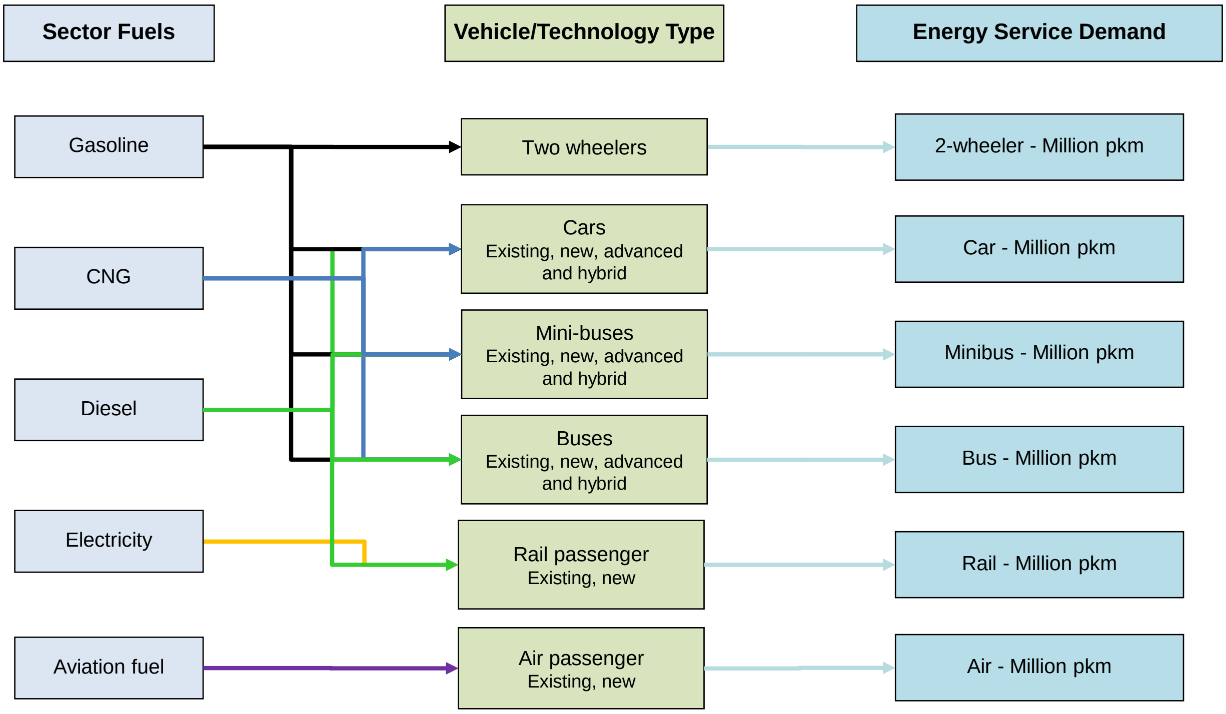


Figure 31: Transportation Passenger Travel RES

Figure 32 shows that passenger transport fuel use grows by 102% between 2014 and 2030, and that Light Duty Vehicles (LDV) fuel use accounts for over 80% of all passenger transport energy use, and the biggest area of growth is in international aviation, which grows from 10% to 15% of the total passenger transport energy use in 2030.

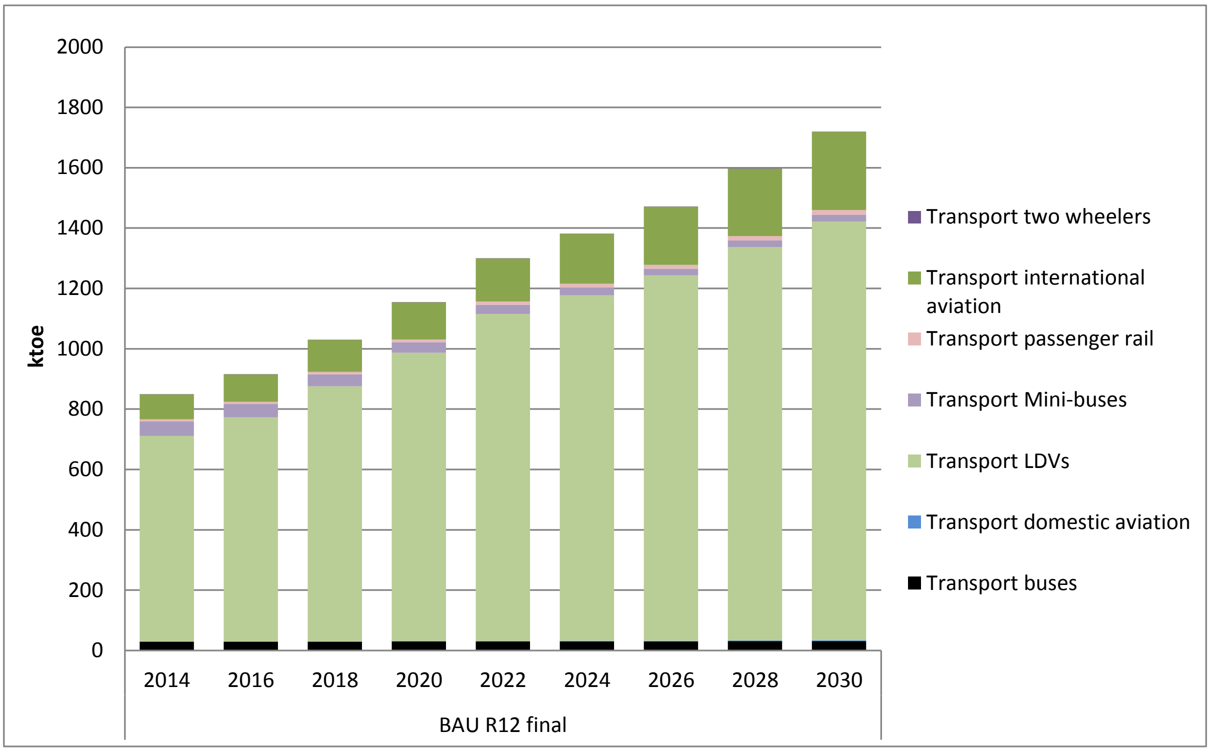


Figure 32: Fuel Use for Passenger Travel by Mode

As shown in Figure 33, passenger transport CO_2 emissions grow by 86% between 2014 and 2030, with LDVs growing from 89% in 2014 to 96% of all passenger transport emissions in 2030. Electricity emissions for the passenger category are for rail transportation, and represent about one-third of the total electricity used in transport.

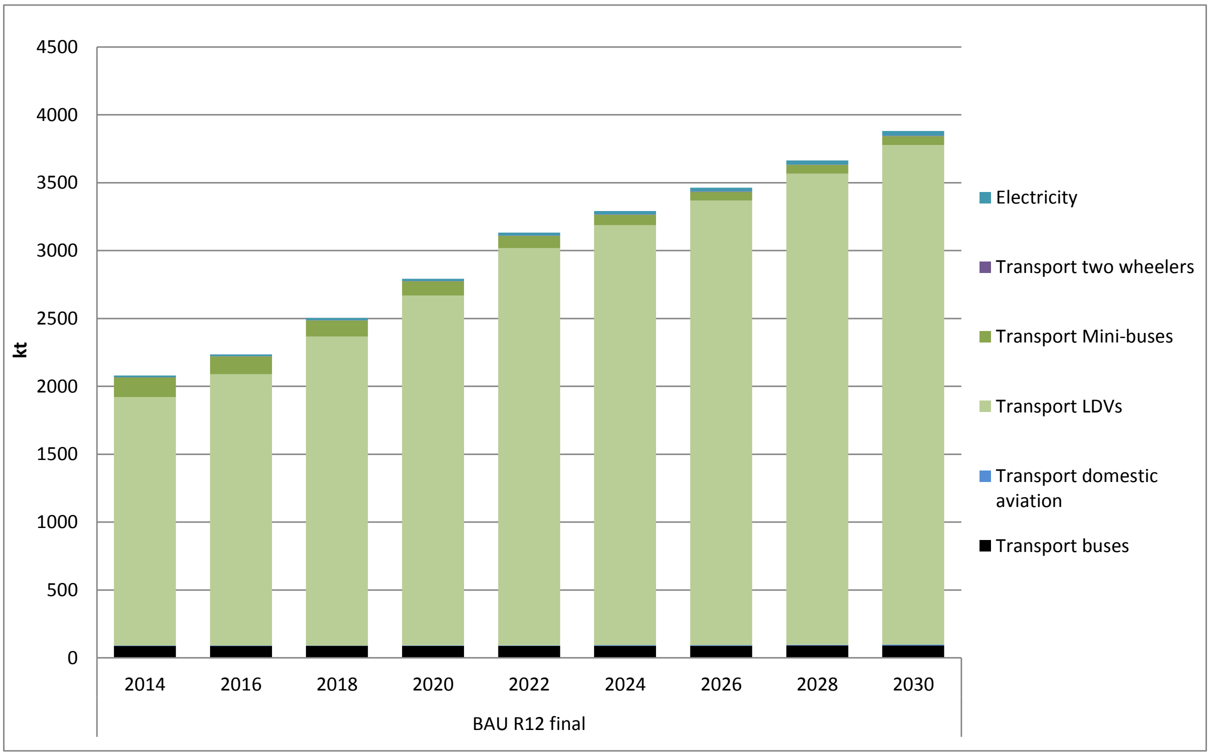


Figure 33: CO_2 Emissions from Passenger Travel by Mode

Figure 34 shows the passenger transport activity by LDV type. Gasoline LDVs remain dominant, but their share decreases from 60% in 2014 to 55% in 2030. Diesel LDVs remain at about 7% and CNG vehicles increase from 32% in 2014 to 39% in 2030.

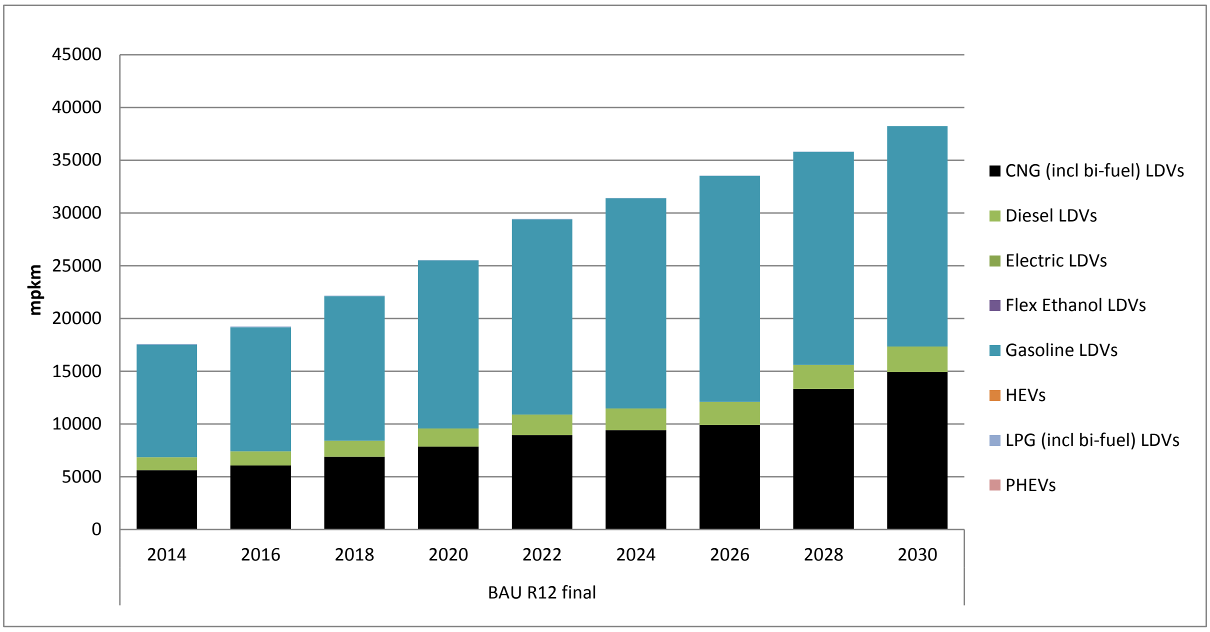


Figure 34: Passenger Transport by Light Duty Vehicles Type

Figure 35 shows a simplified RES diagram for freight transportation. Each freight transportation demand uses a suite of vehicle types to deliver the associated service.

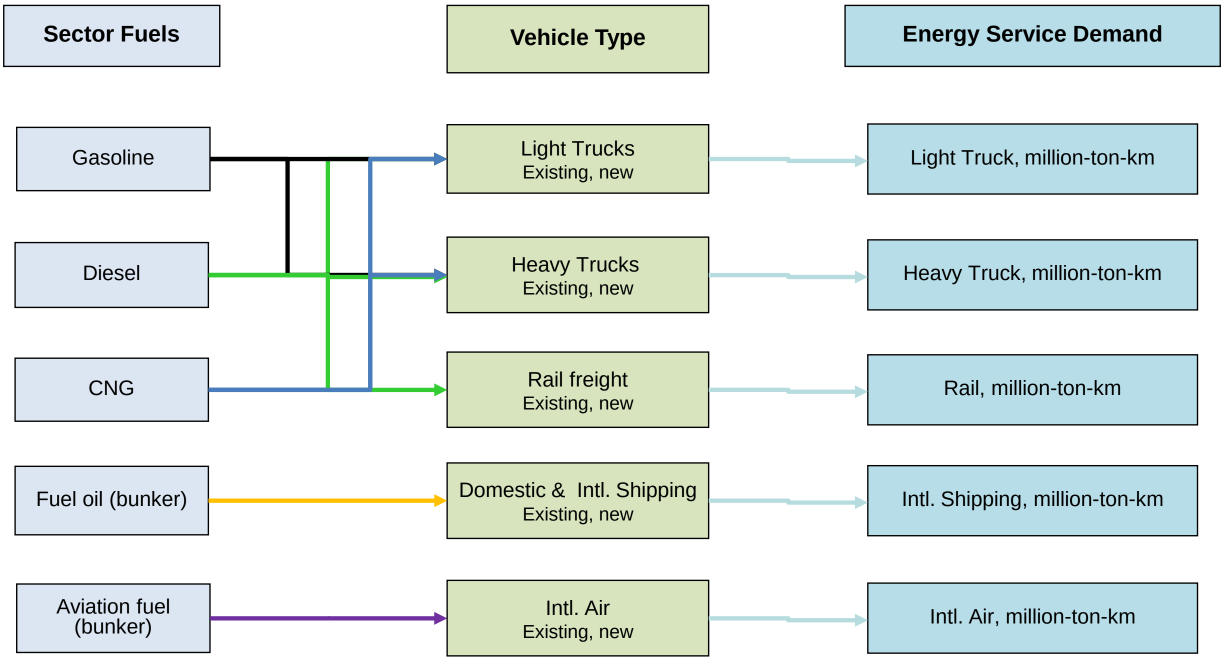


Figure 35: Freight Transportation RES

Figure 36 shows that freight transport energy use increases by 113% between 2014 and 2030, and is dominated by heavy trucks (HGVs), which grows from 60% in 2014 to 73% of freight transport energy use in 2030. Off-road transport is the other major energy use, and while energy use increases, its share of total transport consumption declines from 31% in 2014 to 18% in 2030.

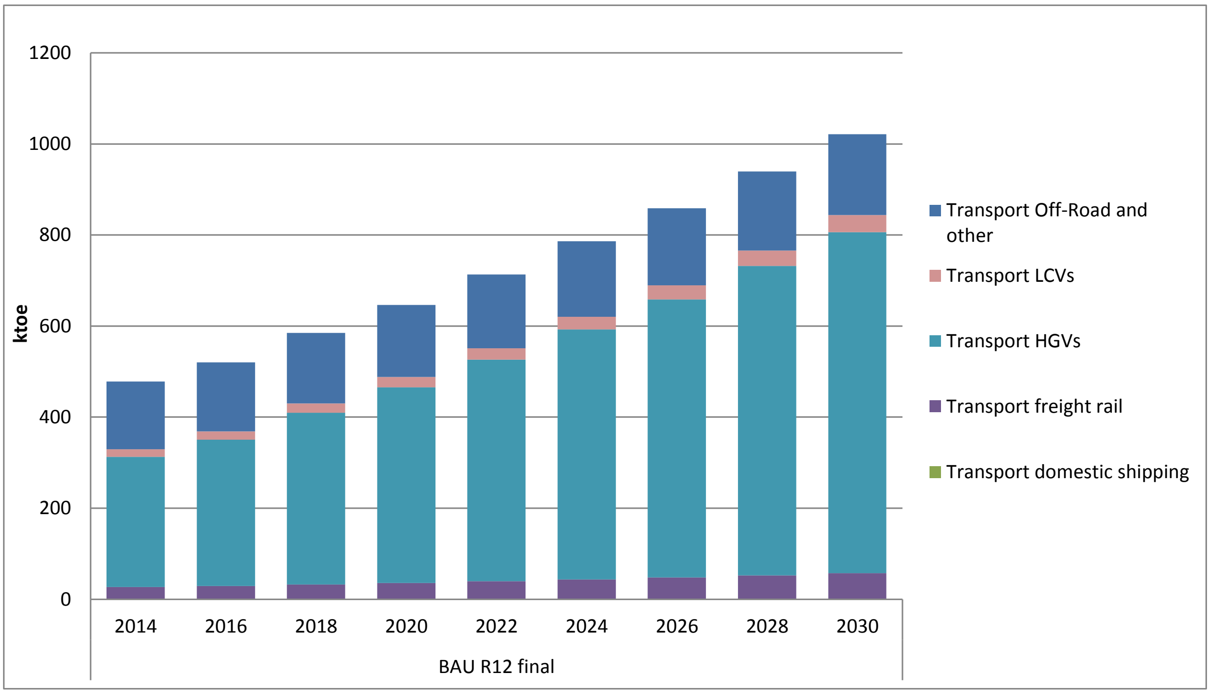


Figure 36: Fuel Consumption for Freight Transport by Mode

As shown in Figure 37, freight transport emissions (excluding bunkers) grow by 109%, with the major growth in emissions coming from heavy trucks, which grow from 63% in 2014 to 76% share of the emissions in 2030. Emissions from off-road transport and light trucks (LCV) comprise the bulk of the remaining growth. Indirect emissions from electricity use come from the rail freight mode.

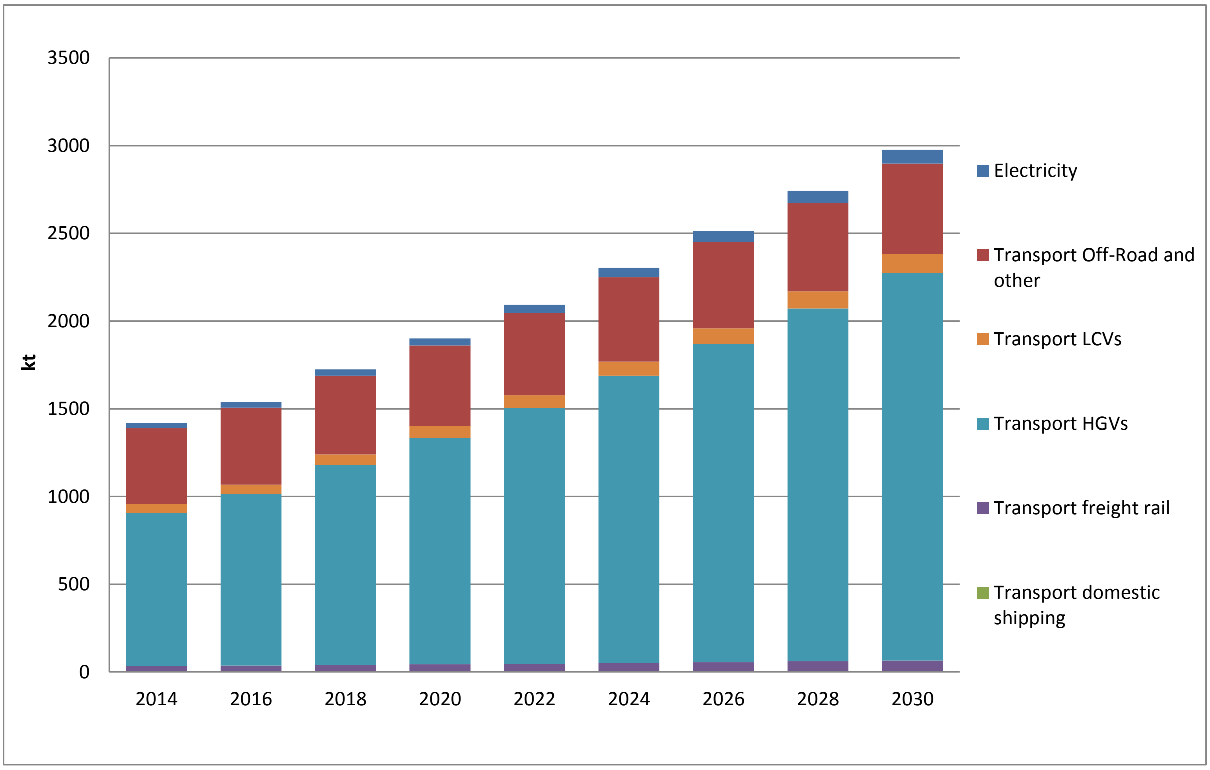


Figure 37: CO_2 Emission from Freight Transport by Mode

3.6 Agriculture Sector Energy Use and GHG Emissions

Energy use in the agriculture sector is small in comparison to the other demand sectors, as shown in Figure 38. As a consequence, CO_2 emissions are also quite small, and do not show in Figure 10, which gives emissions by sector. BAU scenario emissions grow from 25 kt in 2014 to 42 kt in 2030.

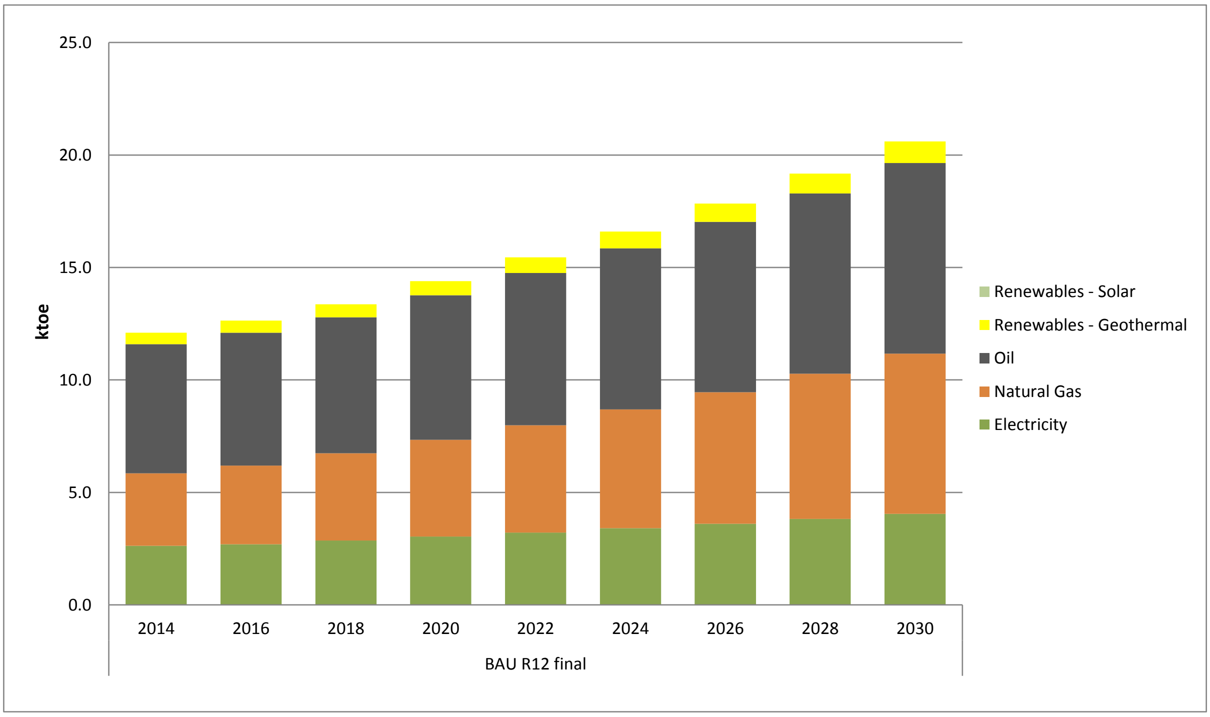


Figure 38: Fuel Consumption for Agriculture Sector

4 Energy Intensity

Figure 39 shows the final energy intensity per GDP for the BAU scenario. The decline from 0.31 to 0.25 is due to general efficiency improvements as new technologies replace existing stock throughout the energy system. Figure 40 shows the energy sector GHG emissions per GDP, which declines from 0.77 in 2014 to 0.67 in 2030.

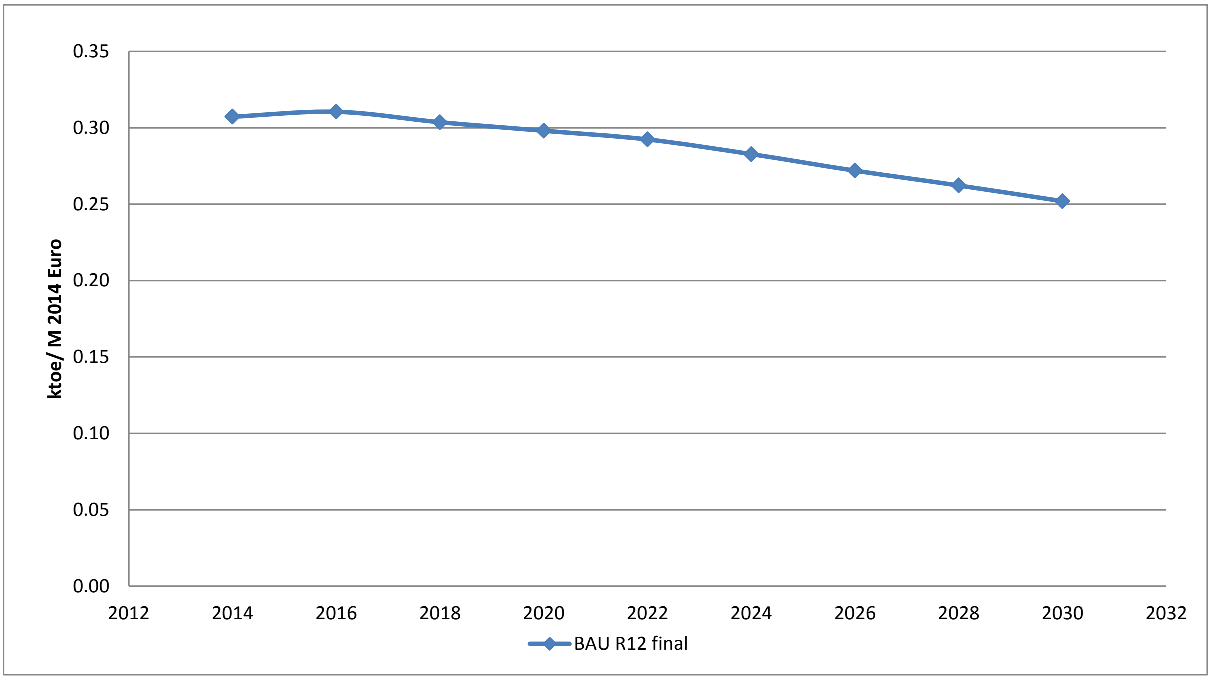


Figure 39: Final Energy Intensity per GDP for BAU Scenario

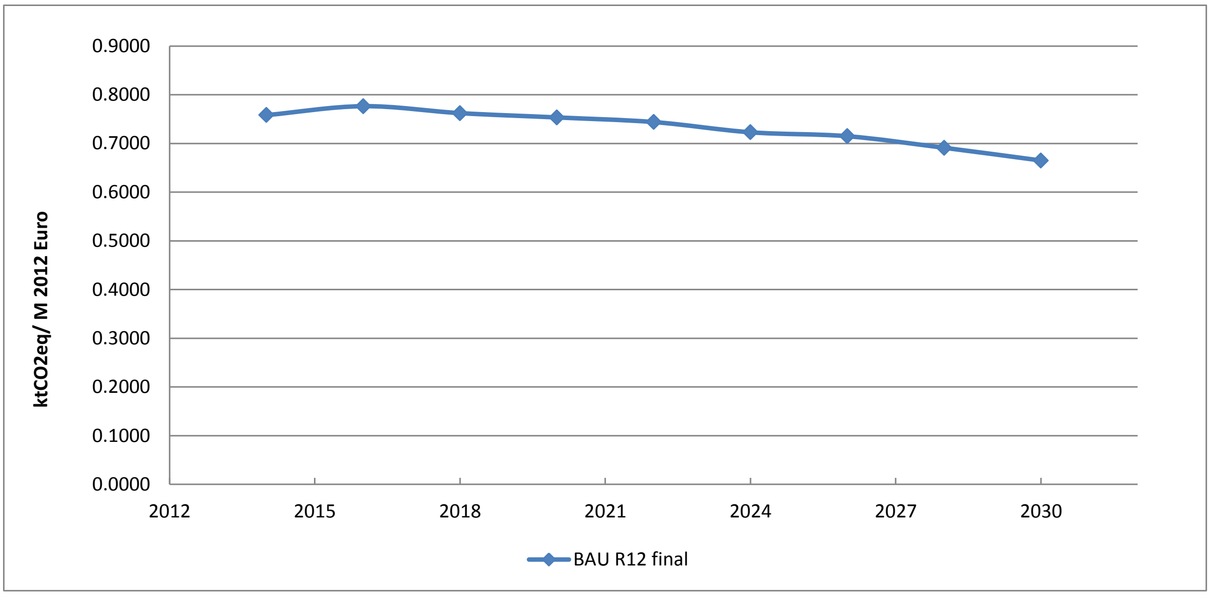


Figure 40: GHG Emissions Intensity per GDP for BAU Scenario

5 Alternate GDP Scenarios

This section presents summary results for three alternate GDP scenarios. They represent different cases for economic growth and possible population growth. Table 2 presents the GDP and population growth assumptions for all four scenarios. An Excel workbook accompanies this report, which provides tabular values for all the charts presented in this report.

In addition to the BAU scenario, the following alternative demand projections were developed with differing GDP and population growth assumptions, as proposed by the Ministry of Environment and Natural Resources Protection.

- **High GDP Growth:** GDP growth of 7.3% and Population growth of 0.0%
- **Pessimistic GDP Growth:** GDP growth of 3.6% and Population growth of 0.0%
- **Optimistic Growth:** GDP growth of 7.9% and Population growth of 0.5%
- **BAU with Population Growth:** GDP growth of 5.6% and Population growth of 0.5%

Table 2: GDP and Population Growth Assumptions for Alternate Demand Scenarios

Demand Driver	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040
High GDP Growth													
GDP growth	3.5%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%	7.3%
Population growth	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GDP (2014 M Euro)	13,321	15,337	17,658	20,331	23,407	26,949	31,028	35,723	41,129	47,353	54,519	62,769	72,268
Population (1000s)	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730
GDP/pop	3,572	4,112	4,735	5,451	6,276	7,226	8,320	9,578	11,028	12,697	14,618	16,830	19,377
Pessimistic GDP Growth													
GDP growth	3.5%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%	3.6%
Population growth	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GDP (2014 M Euro)	13,321	14,298	15,346	16,471	17,678	18,974	20,364	21,857	23,459	25,178	27,024	29,005	31,130
Population (1000s)	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730	3,730
GDP/pop	3,334	3,572	3,834	4,115	4,416	4,740	5,087	5,460	5,861	6,290	6,751	7,246	7,777
Optimistic Growth													
GDP growth	3.5%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%	7.9%
Population growth	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
GDP (2014 M Euro)	13,321	15,509	18,057	21,022	24,475	28,495	33,175	38,624	44,967	52,353	60,951	70,962	82,616
Population (1000s)	3,767	3,805	3,843	3,881	3,920	3,960	3,999	4,039	4,080	4,121	4,162	4,204	4,246
GDP/pop	3,536	4,076	4,699	5,416	6,243	7,197	8,295	9,562	11,022	12,705	14,645	16,881	19,458
BAU with Population Growth													

GDP growth	3.5%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Population growth	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
GDP (2014 M Euro)	13,321	14,855	16,566	18,473	20,600	22,972	25,616	28,566	31,855	35,522	39,612	44,173	49,259
Population (1000s)	3,767	3,805	3,843	3,881	3,920	3,960	3,999	4,039	4,080	4,121	4,162	4,204	4,246
GDP/pop	3,536	3,904	4,311	4,759	5,255	5,802	6,405	7,072	7,808	8,620	9,518	10,508	11,602

This section provides a summary of the three GDP growth scenarios, with commentary regarding the BAU with population growth scenario.

Figure 41 presents the total discounted system cost for the BAU and three alternate GDP scenarios. The High GDP case shows a 14% increase in total discounted energy system cost, while the Pessimistic GDP scenario shows a 15% reduction on energy system costs. The optimistic demand scenario with both high GDP and population growth shows a 21% increase in energy system costs. The BAU scenario with population growth shows a 1.4% increase in the energy system cost.

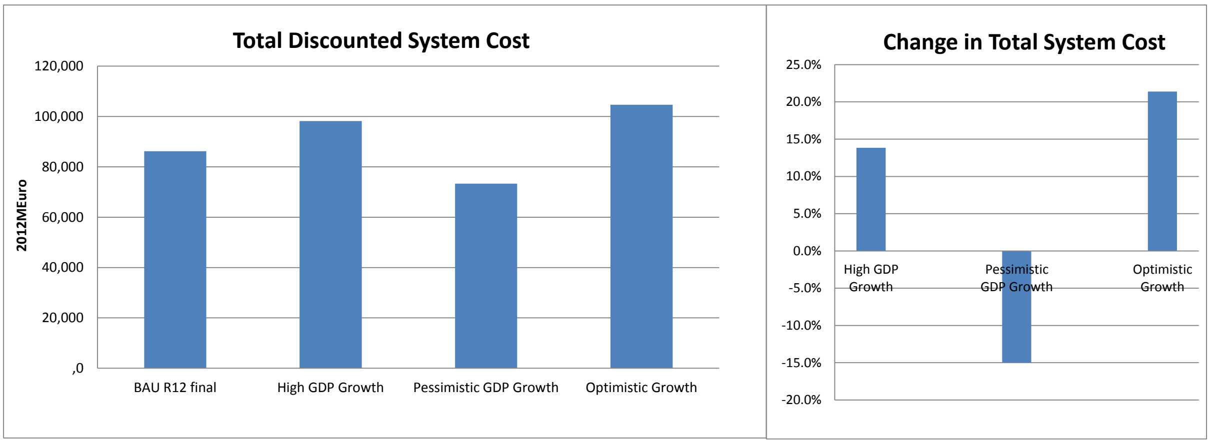


Figure 41: Total Discounted System Cost for BAU and Alternate GDP scenarios

Figure 42 presents the aggregated GHG emissions from the energy system for the BAU and three alternate GDP scenarios. The High GDP case shows 17% higher emissions in 2030, while the Pessimistic GDP case results in about a 15% decrease in 2030, and the Optimistic Growth case shows a 26% increase.

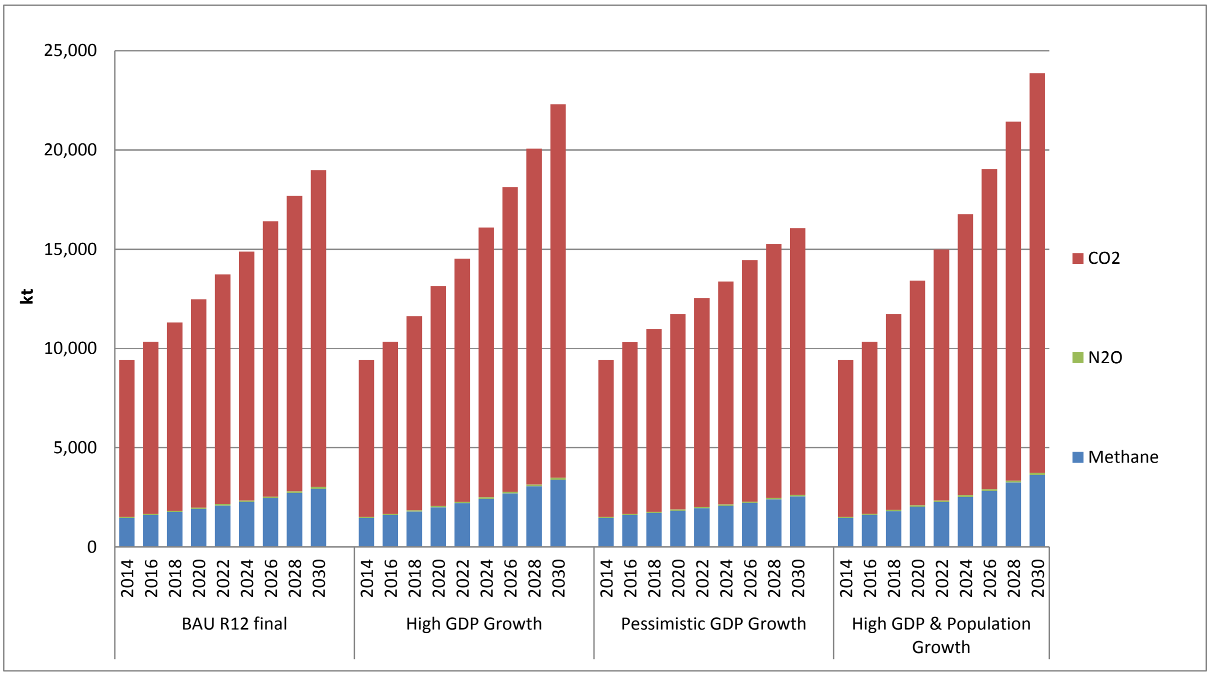


Figure 42: Aggregated Energy System GHG Emissions for BAU and Alternate Demand Scenarios

Figure 43 presents the primary energy consumption for the BAU and three alternate GDP scenarios. The High GDP case shows 16% higher energy use in 2030, while the Pessimistic GDP case results in about a 15% decrease in 2030, and the Optimistic Growth case shows a 24% increase in primary energy use.

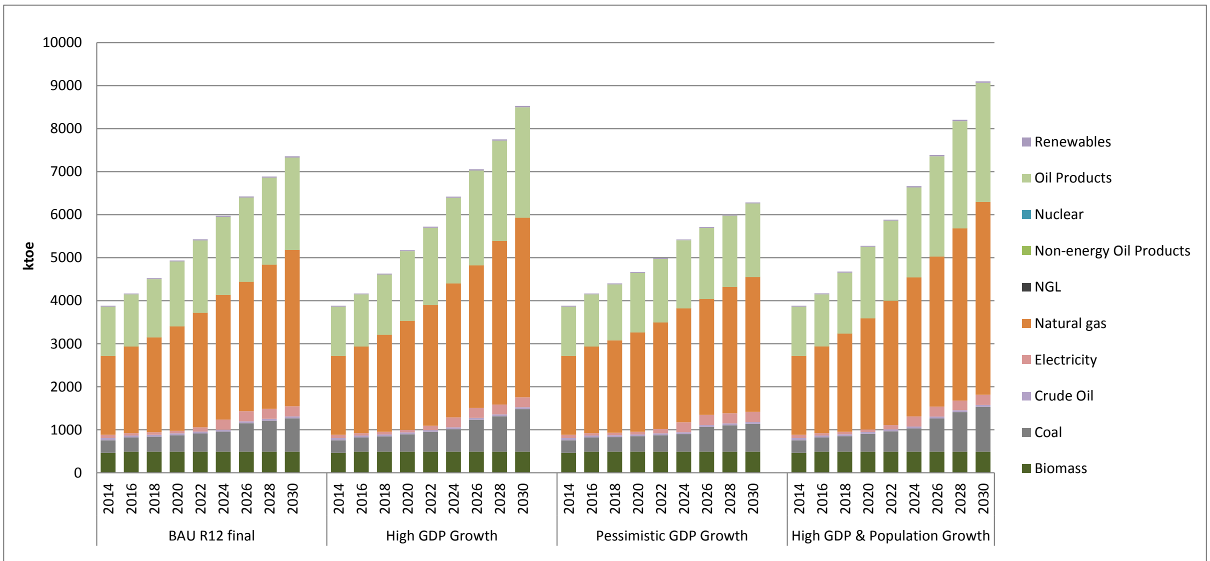


Figure 43: Primary Energy Consumption for BAU and Alternate GDP scenarios

Figure 44 presents the electricity generation by plant type for the BAU and three alternate GDP scenarios. The High GDP case shows 20% higher electricity use in 2030, while Pessimistic GDP case results in about a 16% decrease in 2030, and the Optimistic Growth case shows a 29% increase in electricity generation. However, much of the growth in electricity generation is driven by opportunities for exports and that masks the demand changes due to GDP and population alone.

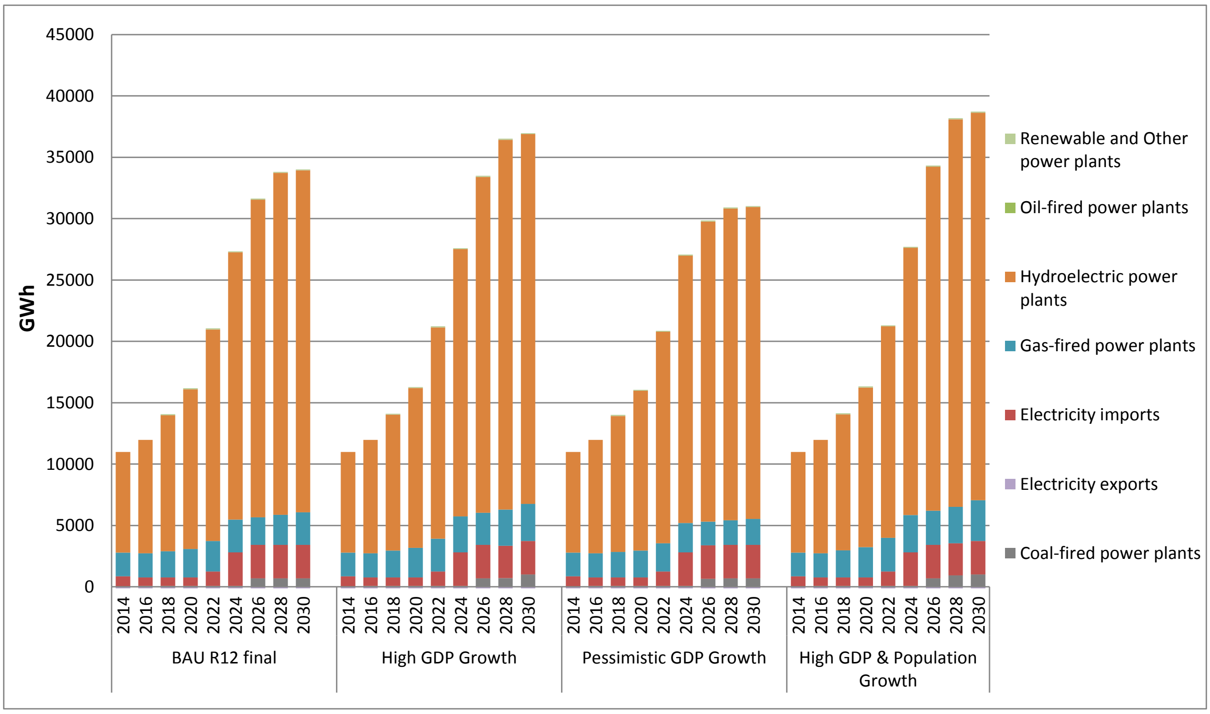


Figure 44: Electricity Generation by Fuel Type for BAU and Alternate GDP scenarios

Figure 45 presents the final energy use for the BAU and three alternate GDP scenarios. The High GDP case shows 17% higher energy use in 2030, while the Pessimistic GDP case results in about a 15% decrease in 2030, and the Optimistic Growth case shows a 26% increase and final energy use.

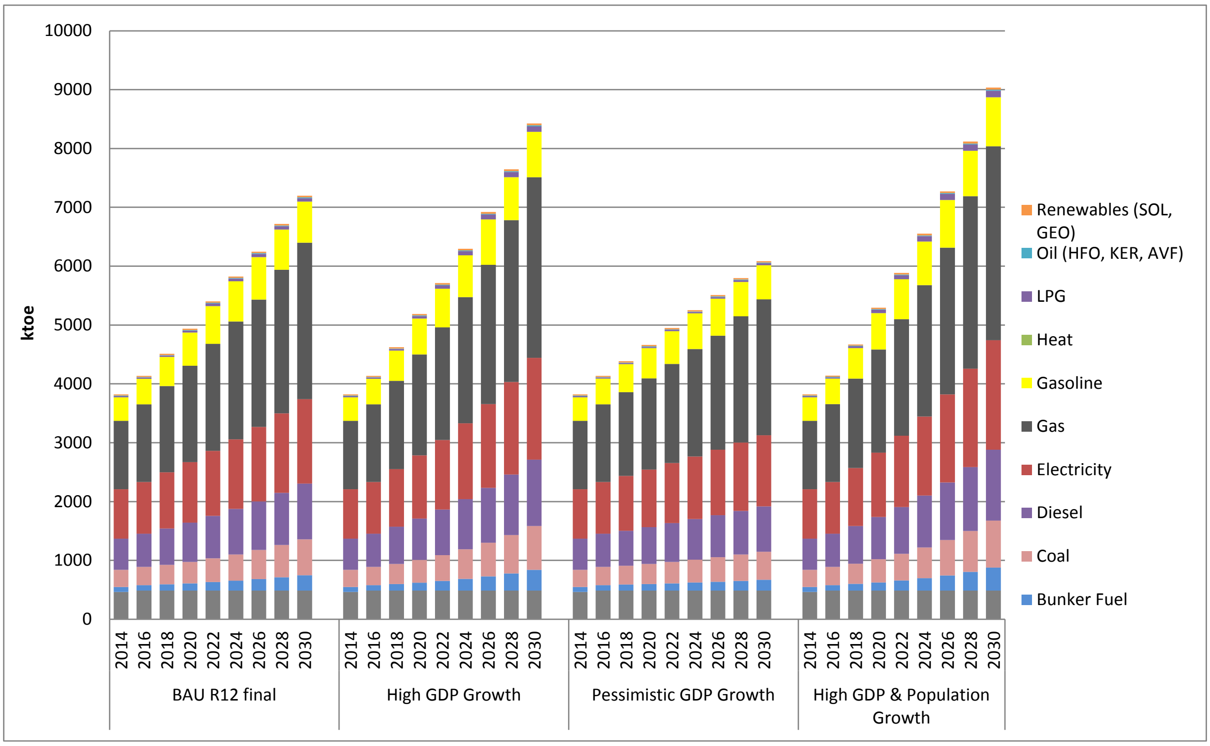


Figure 45: Final Energy Use by Fuel Type for BAU and Alternate GDP scenarios

Figure 46 presents the change in energy intensity for the BAU and three alternate GDP scenarios. The Pessimistic GDP scenario shows the least improvement, while the High GDP and Optimistic Growth scenarios show similar improvements.

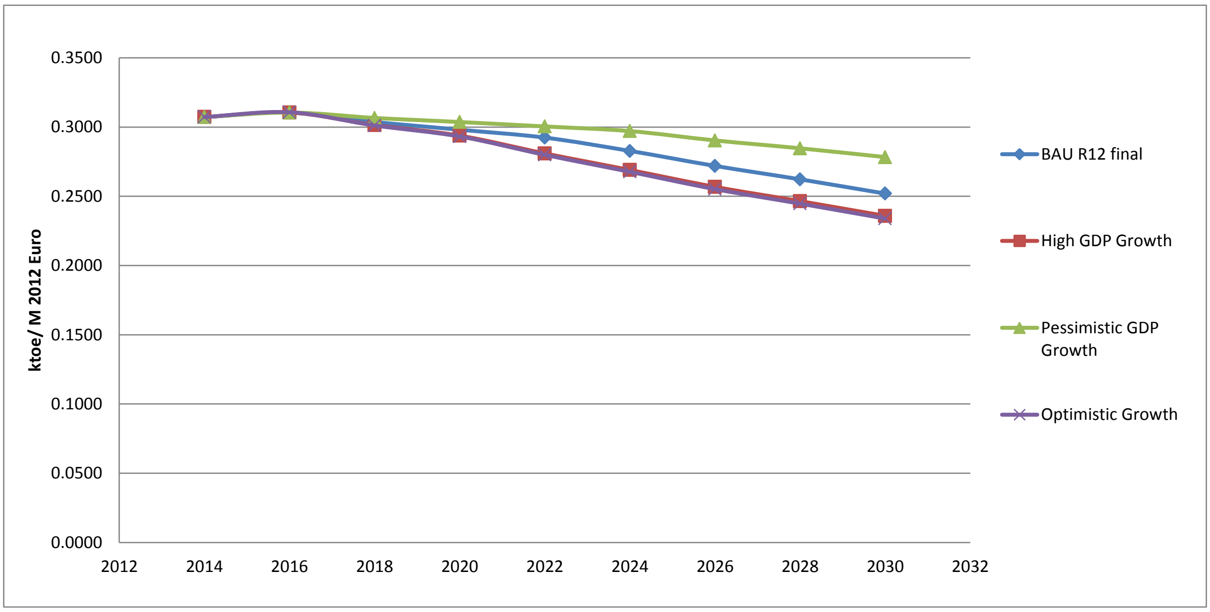


Figure 46: Energy Intensity for BAU and Alternate GDP scenarios

Appendix A: Summary of Updates to the MARKAL-Georgia model

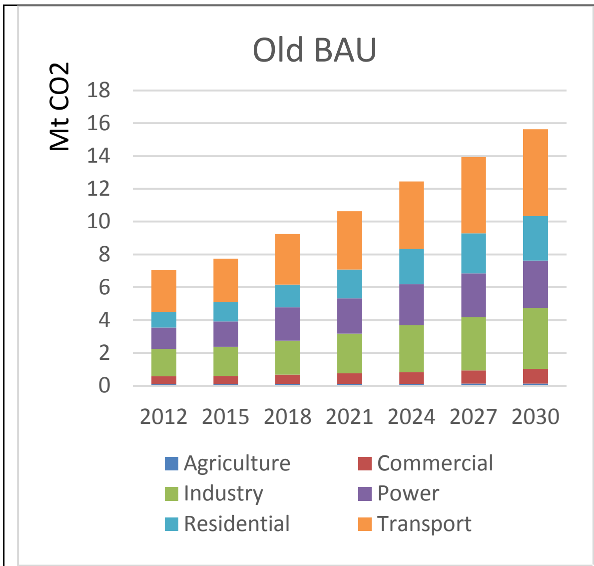
A restructuring and updating of the MARKAL-Georgia model was undertaken by Remissia, in close cooperation with Ministry of Energy Analytic Department (MoE-AD), which was the source of many refinements to the data and assumptions in the model.

As part of the update, all data inputs and assumptions were reviewed and updated as needed. In addition, the model and resulting BAU scenario has been reviewed and quality checked by DecisionWare Group (DWG). In addition, as part of this process, DWG updated of technology database for new demand devices to make it more Georgia specific. The major revisions to the MARKAL-Georgia model are summarized below.

- The base year has been shifted from 2012 to 2014. The energy balance has been updated to match the 2014 Energy Balance (EB) from National Statistics Office of Georgia (Geostat).
- The modeling horizon has been changed to 2040, with 2-year period lengths (previously it was until 2036 with 3-year periods).
- All fuel prices have been reviewed and updated. Data and assumptions for this were prepared by MoE-AD.
- The load profile of all demands has been recalibrated to match detailed 2014 Georgia's electricity system hourly load data, as provided by MoE-AD.
- All Base year (BY) sectoral templates have been recalibrated, in particular:
    - Residential sector has been updated based on EC-LEDS residential survey performed in 2014. This resulted in significant alterations in the template and sectoral end-use splits.
    - The Commercial sector has been recalibrated based on available energy audit data for state owned/commercial buildings.
    - Industry sector has been recalibrated based on a survey of industrial plants which is underway. The information gathered from Rustavi Azoti indicated the misplacement of energy consumption for non-energy purposes and fuel combustion in Chemical Industry in Geostat's Energy Balance, which required the alteration of this Balance. The corresponding letter was sent to Geostat, and information in MARKAL-Georgia has been revised accordingly.
    - Transport sector has been also fully recalibrated. New information on vehicle stocks from Geostat, as well as their surveys of public transport and freight transport for the number of operational vehicles and load factors was used. The HPEP survey was used for mileage and fuel efficiencies of LDVs, and information from Sustainable Energy Action Plans (SEAP) was used for mileages of other types of transport. International sources were used for road vehicles efficiencies other than LDVs. The railway data in MARKAL-Georgia was calibrated based on information gathered from Georgian railway and Information on Tbilisi subway from Tbilisi SEAP monitoring report. The data was calibrated to match the energy consumption in transport sector of the EB.
    - Non-energy consumption sector from the EB has been extended to include more commodities, like lubricants, waxes, etc., that are present in Georgia's energy balance.
    - Agriculture was recalculated.
- Based upon a careful review from Remissia on available new demand technologies, DWG performed a review and updating of this database to ensure it was in-line with current international information and made specific updates where new information was available on the costs and efficiencies of technologies in the Georgian market.
- The information on new planned power plants, as well as projected electricity export-import capacities have been revised with latest available data provided by the MoE-AD.
- Demand projections have been revised as necessary to include some new parameters such as penetration of hot water service, etc.

- User constraints that control the fuel switching behavior and penetration of advanced technologies has been revised to enable more flexibility in this regard for policy runs.
- The energy related emission factors (both for fuel combustion as well as fugitive emissions) have been reviewed and incorporated in the model. To check the calibration of emission inventory and since there is no official emission inventory for 2014, the 2014 emission inventory was prepared using UNFCCC IPCC software for national. MARKAL-Georgia outputs were compared with this inventory and calibrated to get a complete match.
- Other model inputs have also been revised as needed.

There have been also many minor revisions needed to ensure base year calibration and smooth BAU behavior. The efforts until now were focused on updating for the BAU. Figure 47 show the CO_2 emission projections in energy sector in BAU scenario until 2030 (with 3 year periods) and new BAU scenario (with 2 year periods). As the figure shows, the total CO_2 projections have not been changed significantly and in both cases range between 15,600-16,700 kilotons of CO_2, but the distribution between sectors is altered with increased Transport sector's share and decreased shares of Agriculture (fuel combustion) and Power sectors.



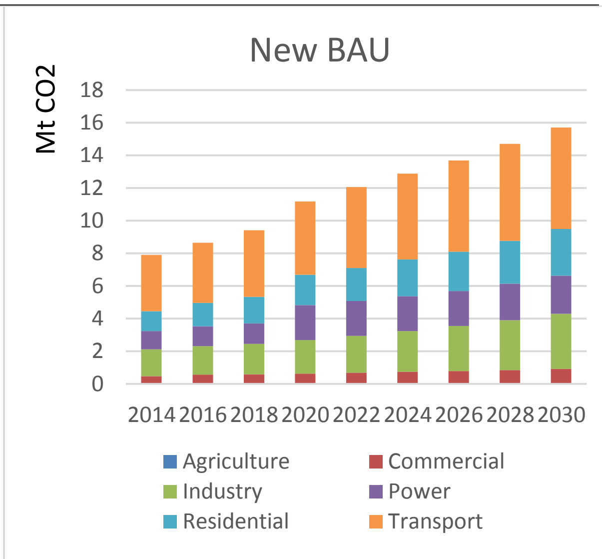


Figure 47: CO_2 Emissions in Old BAU (2012-2030) and new BAU (2014-2030) Scenarios

More significant difference is observed for methane projections which are due to reduced losses in natural gas distribution network in 2014 Geostat EB, which results in reduction of fugitive methane emissions. N_2O emissions from incomplete combustion are almost unchanged.